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Econometric Generalizations of the Ohio Hog-Pork Industry in Interregional Competition

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CONTENTS

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THOMAS T. STOUT, ERNEST R. BENTLEY
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SUMMARY

The analysis employed transportation and spatial equilibrium models to obtain generalizations of the interregional pattern of product shipments in the hog-pork sector of the livestock-meat economy in 1960 and 1975. The study provided a basis for recognizing the present and future competitive potential of hog production and slaughter in Ohio. The analysis generalized optimum hog procurement areas, optimum market areas for the distribution of pork, revealed the competitive strength of the industry in surrounding states, indicated regions where slaughter locations might be optimized, and estimated regional pork price and consumption patterns in both time periods.

In total, Ohio was a net importer of slaughter hogs and of pork in 1960 and similar conditions are anticipated for 1975. Western Ohio, as a separate region, was an exporter of hogs and pork in 1960. While that region may be expected to import hogs in 1975, it may be among the major regional exporters of pork to Eastern markets at that time. Slaughter activity in Western Ohio in 1975 may represent a very favorable circumstance in terms of location within the major hog-producing region of Ohio and Indiana, and location on the western edge of large consumer markets in Eastern Ohio and neighboring eastern states.

Generally, shifts in hog production and slaughter may be expected to continue throughout the United States and to fall into three broad categories: (1) Conditions favorable to slaughter location in terms of reduced total transportation costs may remain largely undeveloped in the southeastern states by 1975; (2) Corn Belt fringe areas such as Kentucky and Tennessee, Wisconsin and Minnesota, and the northern and central Great Plains may witness an over-development of slaughter activity relative to regional production levels; and (3) Transport cost considerations suggest that favorable conditions for slaughter location in the central Corn Belt will continue to exist in 1975.

INTRODUCTION

The geographic distribution of livestock production, livestock slaughter and meat consumption in the United States creates an interstate commodity flow of great complexity. This product movement becomes quite fluid when it occurs in response to an efficient system of product quality standards, and intermarket communication and transportation. Under such conditions the continental United States assumes the essential attributes of a market area. The concept of market area "implies not only a territory within which forces of supply and demand act upon price in such a way that price changes in part of the area quickly affect prices in another part, but also that prices tend to differ between market places only by the cost of transportation to central location of utilization."[1] That product shipments and price patterns do tend to conform to the precepts of market area performance has been rather carefully demonstrated by past research.[2]

Within a market area individual states or regions assume a competitive relationship. Firms and industries within the respective regions act to maximize their comparative regional advantages or minimize their comparative disadvantages. It is advantageous for individual states or regions therefore to understand the nature of their comparative position, recognize the interregional competitive relationships that are relevant, be aware of the economic forces to which they respond, and to incorporate these valid considerations in their anticipation of the future.

But to the industries involved, measurement of the evident complexities is a task of impracticable proportions. The livestock-meat industry of Ohio, an important component of the total economy, is a composite of many small firms. Information descriptive of the industry is not available to the firm. Decisions are, as frequently as not, intuitive insights based upon a lifetime of experience. Advantages accrue to the firms that are best informed by virtue of size, capital investment in specialized skills or other attributes not characteristic of the small firm. This study constitutes one method of evaluating the economic forces affecting the industry's position in a national market.

Objectives of the Study[3]

The study incorporates linear programming techniques in generalizing optimum interregional patterns of trade in the hog-pork sector of the livestock-meat economy. Optimum patterns are defined as those interregional shipments which minimize the transportation costs consistent with each region either receiving shipments to balance its production deficit or shipping any surplus product which it might have. Shipment patterns, transportation costs, prices and price differentials generated from the analysis, and projections of change representing 1975 conditions may be evaluated from the perspective of the Ohio industry and implications drawn with regard to their impact upon producers, packers and consumers in Ohio.

The Data Yield of Transportation and Spatial Equilibrium Models

Both transportation and spatial equilibrium models seek to determine optimum shipment patterns of a product among three or more

[1]Stout, Thomas T., and R. L. Feltner, "Price Relationships in the Market for Slaughter Hogs in Indiana," Indiana Agricultural Experiment Station Research Bulletin 746, Lafayette, June, 1962.

[2]Ibid. Also, see Bredo, William, and A. S. Rojko, "Prices and Milksheds of Northeastern Markets," Northeast Regional Publication Number 9, Massachusetts Agricultural Experiment Station, Amherst, August, 1952.

[3]This study was conducted under Ohio Agricultural Experiment Station Project (Hatch) 237, "Methods, Procedures, and Analysis of Livestock Procurement by Ohio Slaughterers and and Economic Importance of Procurement on Livestock Marketing Agencies."

market places within a market area where the amount of the commodity produced is equal to the amount consumed.[4] Using a transportation model, an optimum shipment pattern is reached when all regional requirements have been satisfied and total transportation costs have been minimized. The solution yields the total transportation bill and discloses the direction and volume of trade between each possible pair of regions. When the more penetrating spatial equilibrium approach is employed, the equilibrium relationship discloses not only volume, direction, and total cost of shipment, but consumption and price per unit in each region such that production equals consumption for the market area. An optimum pattern of interregional trade is attained when total transportation costs have been minimized and therefore product value added by transportation has been maximized and is equal to the transportation bill.

Data and Method

Six optimum shipment solutions are reported in the study. Optimum conditions in 1960 were generalized with three 27-region United States models. Projected estimates of all necessary programming inputs were then obtained by regions. Three 29-region United States models were then developed to approximate optimum shipment patterns for 1975. While the methodology and its application remained similar to that developed in past research,[5] certain significant variations were incorporated to obtain insights that might otherwise remain unquantified: (1) Three stage models were employed to obtain more penetrating approximations of industry procurement and distribution patterns. Optimum trade patterns are developed for live hogs moving from production to slaughter, and for retail-equivalent weights of pork distributed from slaughter locations to consuming centers. Additional models present optimum shipment patterns that might exist if slaughter were conducted completely within the production region; (2) Transportation rates have been employed independently of trade volume, but rates are direction-dependent; and (3) Regional boundaries were determined independently of state line in selected instances to provide more meaningful definition to critical production or consumption regions.

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[4]Additional assumptions beyond those implied in the statement are essential to the analysis, among them some that are characteristic of perfect competition: (a) product homogeniety, (b) economic man and his aspirations for profit maximization, and (c) freedom from external control; in this case from barriers to free interregional commodity flow. Moreover, (d) transportation costs are independent of volume (and perhaps direction) of shipment, and (e) regional demand can be represented by known demand functions. Finally, (f) there exists the restriction that shipments may occur only between pairs of regions, one surplus and one deficit, and shipments must originate in surplus regions and (g) cost of shipment within a region is zero.

[5]Theoretical presentations were published as early as 1951. The first empirical applications were published in 1953 and have been succeeded by several others to date. See, for example: Enke, S., "Equilibrium Among Spatially Separated Markets: Solution by Electric Analogue," **Econometrica**, 19:40-48, 1951; and Samuelson, P. A., "Spatial Price Equilibrium and linear Programming," **The American Economic Review**, 42:283-303, 1952. Among the applications to the livestock economy are: Fox, K. A., "A Spatial Equilibrium Model of the Livestock-Feed Economy in the United States," **Econometrica** 21:547-566, 1953; Judge, G. G., and T. D. Wallace, "Spatial Price Equilibrium Analyses of the Livestock Economy," (Part 1), Oklahoma Ag. Expt. Sta. Technical Bul. TB-78, June, 1959; and Kelly, P. L., et. al. "The Competitive Position of Kansas in Marketing Hogs," Kansas Ag. Expt. St. Tech. Bul. 118. October, 1961.

A complete methodological review dealing with the construction of optimum shipment patterns is contained in Appendix B.

Usefulness of the Analytical Technique

The analysis is useful in investigating procurement and distribution patterns in several essential points: (1) Three-stage models provide meaningful generalizations of raw material sources and product markets for the Ohio meat packing industry; (2) Alternative as well as optimum procurement and distribution possibilities are disclosed; (3) Solutions incorporating demand elasticities provide estimates of unit price and per capita consumption in optimum and potential markets for the Ohio product. (4) The cost to the industry of non-optimum alternatives is estimated; (5) States or regions that are in direct competition with the Ohio industry for hog procurement or pork markets are disclosed and the nature of the relationship is quantified in price differentials relative to Ohio; (6) Regions which are potential competitors for identical markets are tentatively identified; and (7) Approximations of 1975 conditions provide Ohio producers, livestock markets, packing plants and policy makers with a basis for future planning.

Limitations of the Analytical Technique

Transportation and spatial equilibrium models provide penetrating approximations of macro-economic activity. Perhaps their principal contribution rests in their ability to quantify economic concepts that, by their very complexity, heretofore have remained qualitative. But it is difficult to regard the accompanying accomplishments of programming techniques as conclusive. Such models, confronted by the complexity they presume to explain, may be always subject to the accusation that the conclusions were derived from information much too limited in scope.

The models deal only with net product flow, yet a great deal of trans-shipping does occur. Data limitations force estimates of regional consumption from equations containing national parameters. The models seek to optimize conditions in the hog-pork sector as a separate aspect of the livestock-meat industry when in circumstance the hog-pork sector is so interrelated as to be inseparable from the total activity.

It is not self-evident that transportation and spatial equilibrium models generate policy alternatives more effectively than can astute industry management. But it seems apparent that they provide a useful supplement in aiding management decisions, particularly in long-range planning. It seems probable that continued effort in application of these methods will find them increasingly useful in quantifying and forecasting the complex economic phenomena that constantly present themselves.

SHIPMENT PATTERNS FOR 1960

Three optimum shipment patterns were developed for 1960. The transportation model approach was used in determining an optimum shipment pattern for live hogs moving from 1960 surplus production areas to 1960 slaughter locations. Spatial equilibrium models described a mimum cost pattern for shipment of pork from 1960 surplus slaughter locations to surplus consumption areas, and a minimum cost pattern for shipment of retail-equivalent weight of pork from production to consumption assuming all slaughter occurred at point of live production.

Regional Demarcation

The three 1960 models are based on a 27-region disaggregation of the continental United States. Generally, regional boundaries follow state lines, but there are exceptions. For example, Ohio exhibits characteristics of both eastern population density and Corn Belt productive capacity. Regions 10 and 11 (Chart A) attempt to present these features in separate regions. Region 2 (Chart B) encompasses New York exclusive of the New York City metropolitan area and Region 5, Pennsylvania, excludes Philadelphia. These two urban complexes are included with New Jersey to form Region 3. Generally, states surrounding Ohio were presented as separate regions to permit a critical examination of pork markets and hog procurement sources most meaningful to the Ohio packing industry. Larger regions were used in areas indirectly related to Ohio or in locations where production or consumption were less concentrated. In all cases shipments to or from each region are figured in terms of key cities selected as basing points and listed in Table 1.

Basic Data Requirements

Transportation models require regional estimates of production and consumption of the product, plus estimates of per unit transportation costs. Spatial equilibrium analysis, which recognizes price as a determinant of quantity consumed, requires additional estimates of this price-quantity relationship. Table 1 summarizes the 1960 data that was obtained from published sources. USDA estimates of commercial slaughter and farm slaughter were aggregated to provide total slaughter volume. Marketings plus farm slaughter, adjusted to total slaughter, represent relevant hog production. Per capita disposable income was used to represent consumer purchasing power. Population estimates, applied to per capita pork consumption (1960 = 65.3 pounds) figures provided estimates of regional and total consumption.

Transportation Costs: Analysis of basic truck transportation cost data[6] revealed a substantial difference in liveweight transportation charges between Eastbound and Westbound shipments originating in the North Central States. Two direction-dependent sets of liveweight transportation functions were therefore developed. Regression analysis indicated that a blend of one linear and one quadratic function was

[6]A survey of hog transportation charges was completed in 1959 by the North Central Regional Livestock Marketing Research Committee. Data from 436 hauls were made available to the authors by the regional coordinator of that project, R. R. Newburg, Department of Agricultural Economics, Ohio Agricultural Experiment Station.

CHART A—Ohio Regions and Basing Points, Transportation and Spatial Equilibrium Analysis, 27 and 29—Region Models, United States, 1960 and 1975.

Source: Original Data

appropriate in estimating each set of transport costs.[7] The linear equations generated marginal rates for Eastbound shipments that were more than three cents per hundredweight higher than those for Westbound shipments. The principal differences in the two quadratic equations rested in a difference of 100 miles in their applicability.

Transportation charges for meat were derived with a quadratic function developed under current research at the University of Illinois.[8] Both truck and rail rates were combined in the single equation. The rates which it generated were employed independently of both volume and direction of shipment.

The Consumption Function: The determination of surplus- and deficit-producing regions to be used in spatial equilibrium analysis is

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[7]Equations used to generate Eastbound live transport costs were:

(1) $C_{ij} = 14.6744 + .15315M_{ij} - .00004792M^2_{ij}$ (0 — 300 miles)

(2) $C_{ij} = 12.9834 + .14640M_{ij}$ (300 — 2000 miles)

C_{ij} = transport cost in cents per hundredweight from region i to region j.

M_{ij} = highway mileage from region i to region j.

Equations used to generate Westbound live transport costs were:

(3) $C_{ij} = 13.5814 + .16054M_{ij} - .00008325M^2_{ij}$ (0 — 400 miles)

(4) $C_{ij} = 17.6260 + .11544M_{ij}$ (400 — 2000 miles)

[8]The transportation function for pork was made available to the authors by George G. Judge, Department of Agricultural Economics, University of Illinois, and was developed by Judge and associates in connection with research in progress at that institution.

(5) $C_{ij} = 21.4856 + .1929M_{ij} - .00001979M^2_{ij}$ (0 — 4000 miles)

C_{ij} = transport cost in cents per hundredweight from region i to region j.

M_{ij} = highway mileage from region i to region j.

Table 1 — **Hog Production, Total Hog Slaughter, Human Population, and Disposable Personal Income, by Regions, United States, 1960**

Region	State	Basing Points	Hog[1] Production (1,000 lbs.)	Hog[2] Slaughter (1,000 lbs.)	[3] Population (1,000)	[4]Disposable Income ($) Per Capita
1	Vt., N.H., Me.. Kans., Conn., R.I.	Boston	54.535	149,265	10,509	2,161
2	N.Y. (NYC excluded)	Syracuse	47.862	232,925	6,087	2,321
3	N.J., N.Y.C., Phila.	Perth Amboy	31,806	762,515	21,105	2,445
4	Md., D.C., Del	Baltimore	64,266	201,020	4,311	2,295
5	Pa. (Phila, excluded)	Harrisburg	168 216	342,823	6,976	1,956
6	Va.	Richmond	194,470	521,098	3,967	1,653
7	W. Va.	Charleston	34,406	59,733	1,860	1,544
8	N.C., S.C., Ga.	Columbia	1,038,296	968,037	10,881	1,412
9	Florida	Tampa	95,445	140,717	4,952	1,740
10	Eastern Ohio	Cleveland	179,545	459,777	5,319	2,074
11	Western Ohio	Dayton	740,257	575,617	4,387	2,091
12	Michigan	Lansing	267,632	373,762	7,823	2,073
13	Indiana	Indianapolis	1 760,849	1,251,356	4,662	1,947
14	Kentucky, Tenn.	Bowling Green	841,104	1,017,846	6,605	1,402
15	Ala., Miss.	Birmingham	471,576	416,616	5,444	1,279
16	Wis., Minn.	St. Paul	2,163,653	2,254,949	7,366	1,868
17	Ill., Ia., Mo.	Burlington	8,674,253	5,956,456	17,159	2,163
18	Ark., La.	Monroe	215,878	165,725	5,043	1.411
19	N.D.. S.D.	Aberdeen	733,266	604,592	1,311	1,393
20	Neb., Kan.	Grand Island	1,303,227	1,769,919	3,590	1,820
21	Okla., Tex.	Ft. Worth	452,673	633,901	11,908	1,724
22	Mont., Wyo., Idaho	Billings	108,354	124,971	1,672	1,785
23	Colo·ado	Denver	66,982	158,495	1,754	1,962
24	N.M., Ariz.	Gallup	24,307	61,358	2,253	1,694
25	Wash., Ore.	Portland	103,159	288,422	4,622	2,025
26	Nev., Utah	Salt Lake City	21,932	74,494	1,176	1,889
27	California	Fresno	96,456	388,016	15,717	2,403
	United States		19,954,405	19,954,405	178,459	1,969

[1]Statistical Reporting Service, Crop Reporting Board, "Meat Animals, Farm Production, Disposition, and Income by States," U. S. Department of Agriculture, April 1961.

[2]AMS, SRS, ERS, Supplement for 1960 to, "Livestock and Meat Statistics," U. S. Department of Agriculture, Statistical Bulletin No. 230, June 1961. This total includes commercial slaughter plus farm slaughter.

[3]Bureau of the Census, "Statistical Abstract of the U. S., 1961" U. S. Department of Commerce.

[4]Sales Management Magazine of Marketing, "Survey of Buying Power," May 10, 1961.

dependent upon regional consumption estimates. The consumption function used in the study is expressed in the equation:

$$Y_c = 106.7864 - .6863X_1 + .2591X_2 - .0109X_3 \text{ in which:}$$
$$(R_y = .9439)$$

Y_c = U.S. per capita pork consumption in pounds.

X_1 = U.S. average retail price of pork; cents per pound

X_2 = U.S. average retail price of beef; cents per pound (all grades).

X_3 = U.S. per capita disposable income; dollars.

Parameters for the equation were based upon annual observations of the variables over the 11-year period 1950 - 1960 (Appendix Table 1). Regional estimates of pork consumption were derived for each set of iterations by substituting regional values for the independent variables X_1 (pork price) and X_3 (disposable income).[9]

Production-Slaughter Shipments - Transportation Model

An optimum (minimum cost) shipment pattern of live hogs from regions of surplus production to regions of surplus slaughter is presented in Table 2 and Chart B. Total shipments (rim requirements) shown in Table 2 indicate, in thousands of pounds of liveweight, the net surplus or deficit that each region will ship or receive. The underlined values in the field of the table disclose the manner in which optimum trade would occur. The values (all zero or negative) that occupy the cells where no shipments occur represent regional differences in product value minus product transportation costs. These values may be regarded as net loss, in dollars per hundredweight, realized from making these shipments under 1960 equilibrium conditions. For example, shipments from Dayton, Ohio (Region 11) to Fresno, California, (Region 27) would result in a net loss of $1.02 per hundredweight because transport costs are so much greater than the difference in equilibrium market price of the product in the two regions.

In total, there are seven surplus and twenty deficit regions. The minimum transportation bill realized as a result of these shipments is $45,858,219.60 This total transportation bill is determined by totaling the transportation bills (quantity times transportation charge) for the 26 shipments.

Interpretation of this optimum shipment pattern is straightforward. Some results are of particular interest to Ohio hog markets and packing plants. For example, Region 11 (Dayton, Ohio) exports slaughter hogs. Region 10, (Cleveland, Ohio) imports hogs for slaughter. But trade to satisfy net surpluses or deficits does not occur between these two regions. In view of the optimum markets available to Region 11,

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[9] Regional estimates of pork consumption may be derived with the equation:

(6) $Y_{ci} = 106.7864 - .6863\,(X_{po} + d_{oi}) + .2591(74.2) - .0109X_{3i}$ in which:

Y_{ci} = per capita consumption in the ith region.

X_{po} = price per pound of pork in the base region.

d_{oi} = price differential between the ith region and the base region $(X_{pi} - X_{po})$

74.2 = U. S. average price of beef per pound (all grades).

X_{3i} = per capita disposable income in the ith region, dollars:

X_{po}, however, remains an unknown which must be derived with the equation:

$$(7)\quad \sum_{i=1}^{27} P_iY_{ci} = 126.0145 \sum_{i=1}^{27} P_i - .6863\, X_{po} \sum_{i=1}^{27} P_i - .6863 \sum_{i=1}^{27} P_id_{oi} - .0109 \sum_{i=1}^{27} P_iX_{3i}$$

in which P_i = population of the ith region

Since U.S. total pork consumption ($\sum_{i=1}^{27} P_iY_{ci}$) is given (population X 65.3) and is assumed to equal total pork production, the value of X_{po} may be determined by substituting specific values for P_i, d_{oi}, and X_{3i} ($i = 1, 2, \ldots, 27$). Since U.S. beef price has been employed in all regions the term, .2591 (74.2), becomes a constant which has been added to the constant term of equation (6). Values for d_{oi} may be obtained by using the price differentials from the final iteration of a preceeding transportation or spatial equilibrium model.

Table 2 — TRANSPORTATION MODEL, PRODUCTION TO SLAUGHTER: Optimum Shipment Pattern for Slaughter Hogs, Surplus Production Regions to Surplus Slaughter Regions, 27-Region Model, United States, 1960 (Transportation cost — $45,858,219.60)

Deficit Production Region[1]	Surplus Hog Production Regions and Volume of Export							Total Destination Requirement[2]
	8	11	13	15	17	18	19	
1	- .43[3]	- .08	- .09	- .37	94,730	- .86	-1.44	94,730
2	- .63	- .11	- .09	- .49	185,063	- .94	-1.27	185,063
3	- .35	90,764	.00	- .29	639,945	- .82	-1.44	730,709
4	- .30	.00	136,754	- .23	.00	- .02	-1.45	136,754
5	- .43	73,876	100,731	- .29	.00	- .82	-1.45	174,607
6	70,259	- .03	246,681	9,688	- .06	- .54	-1.51	326,628
7	- .43	- .01	25,327	- .14	- .04	- .72	-1.55	25,327
9	- .41	- .90	- .78	45,272	- .65	- .27	-2.32	45,272
10	- .99	- .06	- .05	- .58	280,232	- .87	-1.39	280,232
12	-1.44	- .32	- .20	- .82	106,130	-1.17	-1.42	106,130
14	- .88	- .30	- .09	- .01	176,742	- .30	-1.64	176,742
16	-2.05	- .90	- .62	-1.04	91,296	-1.36	- .55	91,296
20	-1.87	-1.04	- .76	-1.05	466,692	- .86	- .63	466,692
21	-1.38	-1.12	- .83	- .44	131,075	50,153	-1.24	181,228
22	-1.78	- .96	- .69	-1.01	- .02	- .82	16,617	16,617
23	-1.72	- .93	- .65	- .89	91,513	- .55	- .61	91,513
24	-1.30	- .75	- .62	- .45	37,051	.00	- .67	37,051
25	-1.80	-1.01	- .73	- .97	73,206	- .78	112,057	185,263
26	-1.82	-1.03	- .75	- .98	52,562	- .63	- .34	52,562
27	-1.74	-1.02	- .75	- .41	291,560	- .33	- .33	291,560
Total Exports[2]	70,259	164,640	509,493	54,960	2,717,794	50,153	128,674	3,695,976

[1]These may be otherwise regarded as surplus slaughter regions in relations to local hog production.
[2]Thousands of pounds liveweight.
[3]Dollars per hundred weight or cents per pound. The figure represents the discrepancy between difference in equilibrium hog prices and transportation costs between Regions 8 and 1. It may be interpreted to mean that the cost of transportation would have to be lowered by 43¢ per hundredweight or more before hogs could be profitably shipped from Region 8 to Region 1.
Source: Original data.

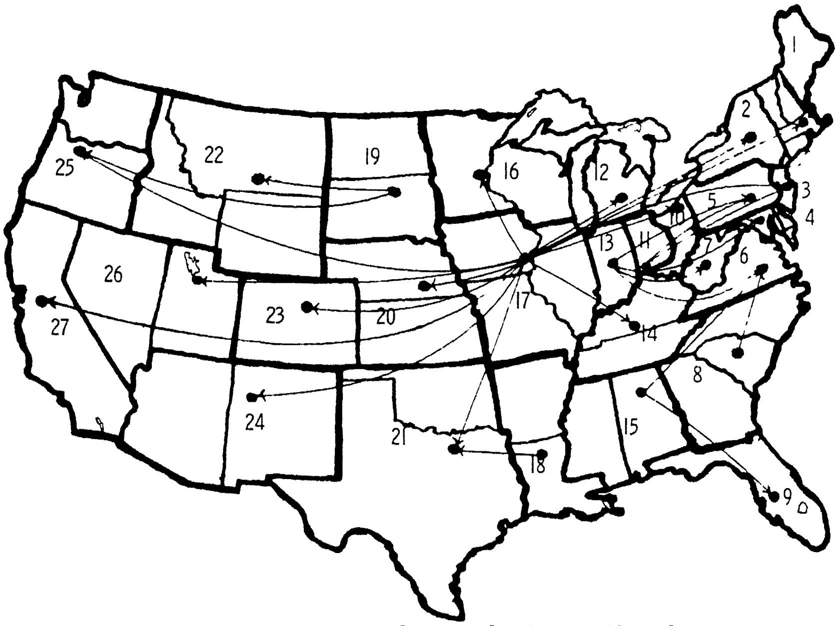

CHART B—Transportation Model, Production to Slaughter: Optimum Shipment Pattern for Pork, Surplus Consumption Regions, 27-Region Model, United States, 1960.
Source: Table 2

shipments to Region 10 would only result in a net loss of $0.06 per hundredweight under 1960 equilibrium conditions. The optimum markets available to Region 11 are Perth Amboy, New Jersey (Region 3), Baltimore, Maryland (Region 4) and Harrisburg, Pennsylvania (Region 5). Even though no product is shipped to Region 4 from 11, it is one of the optimum markets for Region 11 because the net loss of making that shipment would be zero. The model accurately confirms the major market areas to which great quantities of Ohio slaughter hogs actually are shipped. Region 10, Eastern Ohio, on the other hand, is shown receiving the necessary quantity of slaughter hogs from Region 17 (Burlington, Iowa). This does not confirm the usual procurement procedure followed by Ohio packers in purchasing out-of-state hogs. Most of the additional hogs needed to supply Ohio slaughters come from Indiana. The model, however, points out that this procedure costs Ohio packers $0.05 per hundredweight more than would hogs purchased under equilibrium conditions.[10]

Indiana and the Western Corn Belt are both competitors to Ohio hog producers in the export of slaughter hogs to Eastern markets. Western Ohio exporters, at a slight cost relative to the optimum, could find other markets in Virginia, West Virginia, and perhaps Eastern Ohio, but they would be at a competitive disadvantage relative to Indiana, Alabama and Mississippi, North and South Carolina and Georgia, and the Western Corn Belt.

[10]Problems associated with over-aggregation are also possible: In subsequent models the states of Iowa, Illinois and Missouri are presented as separate regions.

Slaughter-Consumption Shipments - Spatial Equilibrium Model

An optimum shipment pattern for pork from slaughter to consumption with a transportation bill of $91,993,031.00 is presented in Table 3 and Chart C. Totals indicate quantity of retail-equivalent amounts of pork, in thousands of pounds, that must be shipped or received by surplus and deficit regions. A rearrangement of surplus and deficit regions is apparent. Region 6 (Virginia), for example, a deficit producer of slaughter hogs, is a surplus producer of pork relative to regional consumption requirements. In total, there are eight surplus pork producing regions and nineteen deficit-producing regions. Some regions, such as Region 8 (Columbia, South Carolina), which were not exporters of slaughter hogs have become net importers of pork due to low regional slaughter capacity relative to both production and consumption.

Region 10 (Eastern Ohio) produces pork in insufficient amounts to supply the regional population. Additional amounts are imported from Region 16 (Wisconsin, Minnesota). Additional cost of two to five cents per pound, pork would be supplied also from Western Ohio, Indiana, and the Western Corn Belt as far west as Iowa. The small amount of excess pork available in Western Ohio is optimally marketed in Pennsylvania and West Virginia, although Ohio is in direct competition with Indiana in these two markets, and with the Western Corn Belt in supplying Pennsylvania. At a slight additional cost, Western Ohio packers could find markets in Eastern Ohio, New York and New Jersey, Maryland and Delaware.

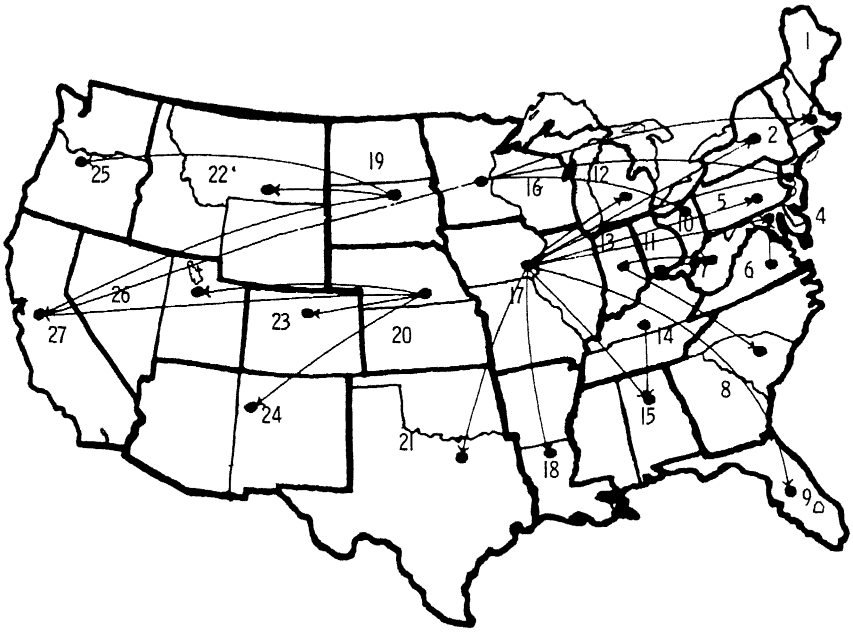

CHART C—Spatial Equilibrium, Slaughter to Consumption: Optimum Shipment Pattern for Pork, Surplus Slaughter Region to Surplus Consumption Regions, 27-Region Model, United States, 1960.

Source: Table 3

Table 3 — SPATIAL EQUILIBRIUM, SLAUGHTER TO CONSUMPTION: Optimum Shipment Pattern for Pork, Surplus Slaughter Regions to Surplus Consumption Regions, 27-Region Model, United States, 1960 Transportation cost — $91,993,031.00)

Deficit Slaughter Region[1]	Surplus Pork Slaughter Regions and Volume of Export								Total Destination Requirement[2]
	6	11	13	14	16	17	19	20	
1	- .27[3]	- .17	- .15	- .62	572,899	- .02	- .75	-.71	572,899
2	- .45	- .15	- .11	- .72	.00	236,623	- .61	-.71	236,923
3	- .12	- .03	- .02	- .51	164,583	653,878	- .77	-.70	818,461
4	30.557	- .01	.00	- .43	-.02	117,864	- .80	-.74	148,421
5	- .27	.00	168,638	- .49	-.01	87,245	- .80	-.71	255,883
7	- .76	52.671	42,981	- .42	-.19	-.08	- .99	-.81	95,652
8	- .32	- .13	209.939	- .12	-.11	-.06	- .88	-.74	209,939
9	- .69	- .34	- .19	- .07	-.13	251.388	- .91	-.65	251,388
10	-1.07	- .04	- .05	- .66	74,301	-.02	- .82	-.73	74,301
12	-1.69	- .35	- .20	- .96	-.04	287.246	- .88	-.81	287,246
15	-1.24	- .42	- .17	118,265	-.20	35,463	- .99	-.66	153,728
18	-1.86	- .81	- .47	- .40	-.29	263,640	-1.07	-.47	263,640
21	-2.43	-1.42	-1.05	-1.03	-.30	441,929	- .80	-.22	441,929
22	-3.19	-2.02	-1.68	-2.23	-11	-.92	39,810	-.32	39.810
23	-3.17	-1.83	-1.47	-1.92	-.32	-.68	- .62	22,800	22,800
24	-2.59	-1.37	-1.20	-1.04	-.33	-.50	- .51	117,484	117.484
25	-2.79	-1.75	-1.45	-1.83	-.01	-.69	127,185	-.20	127.185
26	-2.99	-1.80	-1.47	-1.90	-.26	-.61	- .19	34,194	34,194
27	-2.50	-1.43	-1.13	-1.53	5.983	-.35	90,776	615.103	711.862
Total Exports[2]	30.557	52,671	421,558	118.265	817.766	2.375.576	257.771	789,581	4.863.745

[1]These may be otherwise regarded as surplus consumption regions in relation to local pork slaughter.
[2]Thousands of pounds edible pork, based on a conversion (58.3998%) from liveweight
[3]Dollars per hundredweight or cents per pound.
Source: Original data

Production-Consumption Shipments - Spatial Equilibrium Model

An optimum pattern for shipment of pork from production-oriented slaughter points to surplus consumption regions is presented in Table 4 and Chart D. Over the past several decades relocation of packing plants has shown a clear trend of movement closer to sources of supply. Part of the reason for this has been the lower transportation cost associated with the shipment of meat as opposed to shipment of livestock. The total transportation bill for the shipment pattern in Table 4 reflects this saving. The cost of $121,064,315.50 represents a 12 percent saving over the aggregate transportation bill for the production-slaughter-consumption shipments of the two preceding models.

Should existing trends in relocation continue then, if relative production and consumption among regions remained unchanged, the trend alone would reflect changing markets for the Ohio meat packing industry. Export of live hogs would diminish or disappear. Under 1960 equilibrium conditions, Eastern Ohio would receive supplementary pork from Minnesota-Wisconsin and the western Corn Belt. The export market for surplus pork production in Western Ohio would remain unchanged except that shipments would occur in greater quantities to West Virginia and the position of Wisconsin and Minnesota as a competitor for Ohio market outlets would be somewhat improved. Western Ohio's ability to supply Eastern Ohio would therefore be somewhat impaired, but at a slight cost over optimum, Western Ohio packers would find a new market in Virginia, formerly an exporter of pork.

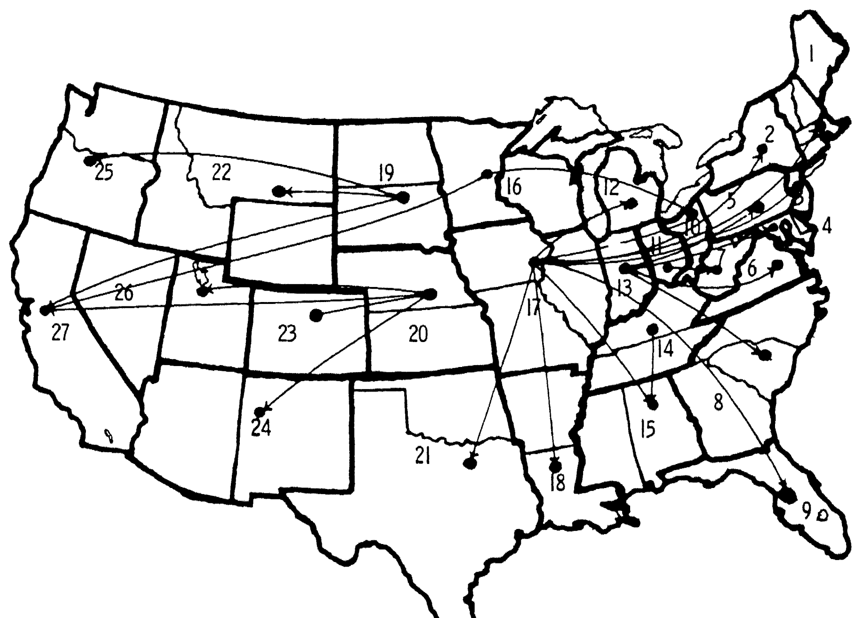

CHART D—Spatial Equilibrium, Production to Consumption: Optimum Shipment Pattern for Pork, Surplus Slaughter Region to Surplus Consumption Regions, 27-Region Model, United States, 1960.

Source: Table 4

Table 4 — **SPATIAL EQUILIBRIUM, PRODUCTION TO CONSUMPTION:** Optimum Shipment Pattern for Pork, Surplus Production Regions to Surplus Consumption Regions, 27-Region Model, United States, 1960 (Transportation cost — $121,064,315.50)

Deficit Production Regions[1]	Surplus Pork Production Regions and Volume of Export							Total Destination Requirement[2]
	11	13	14	16	17	19	20	
1	-.15[3]	-.13	-.60	-.00	628,222	-.75	-.71	628,222
2	-.15	-.11	-.72	-.02	345,060	-.63	-.73	345,060
3	-.03	-.02	-.51	-.02	1,245,404	-.79	-.72	1,245,404
4	-.01	71,720	-.43	-.04	156,608	-.82	-.76	228,328
5	38,210	319,782	-.49	-.03	.00	-.82	-.73	357,992
6	-.05	158,645	-.17	-.09	-.06	-.86	-.74	158,645
7	110,479	.00	-.42	-.21	-.08	-1.01	-.83	110,479
8	-.13	168,908	-.12	-.13	-.06	-.90	-.76	168,908
9	-.34	-.19	-.07	-.15	277,876	-.93	-1.67	277,876
10	-.02	-.03	-.64	166.997	70,905	-.82	-.73	237,902
12	-.35	-.20	-.96	-.06	349,304	-.90	-.83	349,304
15	-.42	-.17	14,916	-.22	106,825	-1.01	-.68	121,741
18	-.81	-.47	-.40	-.31	234,452	-1.09	-.49	234,452
21	-1.42	-1.05	-1.03	-.32	547,766	-.82	-.24	547,766
22	-2.00	-1.66	-2.22	-.11	-.90	49.514	-.32	49,514
23	-1.81	-1.45	-1.90	-.32	-.66	-.62	76,244	76,244
24	-1.35	-1.16	-1.02	-.33	-.48	-.51	139,099	139,099
25	-1.73	-1.41	-1.81	-.01	-.67	235,378	-.20	235,378
26	-1.78	-1.45	-1.88	- 26	-.59	-.19	64,913	64,913
27	-1.41	-1.11	-.51	597.378	-.33	48,011	236,742	882,131
Total Exports [2]	148,689	719,055	14,916	764,375	3.962,422	332.903	516,998	6,459.358

[1]These may be otherwise regarded as surplus consumption regions in relation to local pork production.
[2]Thousands of pounds edible pork, based on a convention (58.3998%) from liveweight.
[3]Dollars per hundredweight or cents per pound.

PROJECTIONS, 1960-1975

Estimates of 1975 interregional shipment activity require projections of production, consumption and commodity transport costs. The necessary projections were derived from original data and from a variety of published sources.

Per Capita Consumption Estimates

Estimates of United States average per capita pork and beef consumption were based on a study by G. E. Brandow in which annual percentage changes in consumption had been determined.[11] The annual changes were estimated by Brandow after consideration of price elasticity of demand for total food, income elasticity of demand, and cross-elasticities of demand between foods and non-foods. The magnitude of changes in per capita consumption estimated by Brandow were (1) -1.01 percent per year for pork and (2) +2.03 percent per year for beef.

The average United States per capita consumption for pork during the time period 1950-1960 was 65.94 pounds (Appendix Table 1). Using 1955 as the mid-point and compounding the -1.01 percent change over 20 years to 1975 yielded a per capita pork consumption estimate of 53.83 pounds. The same time period and procedure resulted in a 1975 per capita beef consumption estimate of 114.26 pounds.

Regional Population Estimates

Percentage changes in state population from 1960 to 1975 were published in 1961 by the Kiplinger Washington editors.[12] These percentage changes were applied to 1960 Bureau of Census population estimates (Table 1) to derive regional population figures for 1975. Estimates for the New York City and Philadelphia metropolitan areas included in Region 3 were estimated by applying a weighted average of the percentage changes in population of New York, New Jersey and Pennsylvania. Total 1975 Ohio population was allocated to Eastern and Western Ohio in the same proportions existing in 1960. Population estimates for 1975 are summarized in Table 6.

Regional Estimates of Hog Production and Slaughter

United States Department of Agriculture estimates of hog marketings and farm slaughter (in thousands of pounds) were totaled, by states, for the period 1947-1961. State totals were aggregated into 28 regions. The two Ohio regions were treated as an aggregate, and Region 17 (Iowa, Illinois, and Missouri) was broken down into its state components. Regional totals were converted to percentage of total United States production to reduce the effect of production cycles.[13] The same procedure was used in compiling a series of annual percentages of commercial hog slaughter plus farm slaughter. The two series (Appendix

[11]Brandow, G. E., "Interrelations Among Demands for Farm Products and Implications for Control of Market Supply", The Pennsylvania State University, College of Agriculture, University Park, Bulletin 680, August, 1961.

[12]The Kiplinger Washington Editors, 1729 H Street, N. W., Washington, D. C. The percentage changes were published as "The Big Growth Ahead" and distributed as an enclosure with the December 23, 1961 Kiplinger Washington Newsletter.

[13]The procedure is not wholly satisfactory. In regions where hog production is either extremely heavy or extremely light, production levels are not particularly responsive to cyclical fluctuations reflected in national production.

Table 5 — Percentage Share of Total Hog Marketings plus Farm Hog Slaughter and Total Commercial Hog Slaughter plus Farm Hog Slaughter, 27 and 29 Regions, United States, 1960 and 1975

Region	Hog Marketings Plus Farm Hog Slaughter			Commercial Hog Slaughter Plus Farm Hog Slaughter		
	1960	1975 Projection[1] Unadjusted	1975 Projection[1] Adjusted	1960	1975 Projection[1] Unadjusted	1975 Projection[1] Adjusted
1	0.28	0.18	0.18	0.75	0.22	0.22
2	0.24	0.12[2]	0.12	1.94	2.20	2.20
3	0.16	0.19	0.19	1.59	2.22	2.21
4	0.32	0.21	0.21	1.01	0.73	0.73
5	0.85	0.42	0.43	3.17	2.81	2.80
6	0.98	0.71	0.72	2.62	3.76	3.74
7	0.17	0.08[2]	0.08	0.30	0.11	0.11
8	5.21	5.81	5.92	4.82	4.47	4.45
9	0.49	0.40	0.41	0.70	0.80	0.80
10	4.59	3.39	3.45	5.19	5.35	5.33
11	—	—	—	—	—	—
12	1.34	1.11	1.13	1.88	1.13	1.12
13	8.85	9.92	10.10	6.27	7.64	7.61
14	4.24	4.14	4.22	5.10	6.54	6.51
15	2.37	1.89	1.92	2.08	1.60	1.59
16	10.73	12.03	12.25	11.31	10.89	10.83
17	43.41	—	—	29.88	—	—
17a	—	24.60	25.06	—	18.71[4]	18.60
17b	—	14.61[4]	14.88	—	4.47[4]	4.45
17c	—	5.35	5.45	—	7.08	7.05
18	1.08	0.36[3]	0.37	0.82	0.47[3]	0.47
19	3.66	4.27	4.35	3.03	2.77	2.76
20	6.66	5.99	6.10	8.87	9.53	9.49
21	2.27	0.96[3]	0.98	3.17	2.12	2.11
22	0.54	0.15	0.15	0.62	0.68	0.68
23	0.32	0.20[2]	0.20	0.80	0.38	0.38
24	0.13	0.08	0.08	0.31	0.41	0.41
25	0.52	0.37	0.38	1.45	1.34	1.33
26	0.11	0.06[2]	0.06	0.37	0.43	0.43
27	0.48	0.60[3]	0.61	1.95	1.60	1.59
Total	100.00	98.20	100.00	100.00	100.46	100.00

[1]Based on arithmetic linear least-squares unless otherwise noted

[2]Compounded percentage change; Asymptotic curve.

[3]Least squares exponential, $Y=ab^x$.

[4]Least squares double log, $Y=ax^b$.

Source: Original Data

Tables 2 and 3) were used in time series analysis to derive regional percentage estimates of production and slaughter for 1975. The percentage estimates of production and slaughter for Ohio were allocated between Regions 10 and 11 on the basis of approximate 1960 conditions, attributing 80 percent of each to Western Ohio. All regional percentage estimates were then totaled and adjusted to 100 percent (Table 5).

Generally, linear least squares projections of arithmetic data were made. Other techniques were used in estimating production in eight regions and slaughter in three regions (see footnotes to Table 5).

The conversion of percentage estimates to pounds was accomplished by relating production and slaughter to known consumption. Since 1975 national pork consumption is estimated at 12,599,288 thousand pounds (1975 population X 53.83 pounds) then production and slaughter in retail - equivalent weight must occur in the same amount. This may be converted to liveweight by dividing consumption by the same constant (.583998) used in the 1960 analysis. Production and slaughter for 1975 were therefore estimated at 21,574,197 thousand pounds. Applying this total to the percentage distribution of Table 5 yielded the regional production and slaughter estimates presented in Table 6.

Disposable Income Estimates

Estimates of per capita disposable income in 1947 dollars were obtained from the University of Illinois.[14] Figures were converted to 1960 dollars and adjusted to the regional arrangement used in this study.[15]

Transportation Cost Estimates

The functions used in generating 1960 transportation rates were employed also in the 1975 analysis. Estimates of percentage increase in rates between 1960 and 1975 were determined, however, so that 1960 rates could be adjusted appropriately. The percentage changes were derived through analysis of time series covering the thirteen-year period 1948-1960 (Appendix Table 4). The index of rail freight rates was deflated by the wholesale price index and the deflated series, in 1960 dollars, was used as the basis for projections.[16]

The projected live animal and meat rates as a percent of the 1960 rates were 117.34 and 114.89, respectively. (Appendix Table 4)

Estimates of Average Retail Price of Pork and Beef

The 1975 United States average retail price of pork was estimated by time series analysis. The same set of time series used in the derivation of parameters for the demand function in the 1960 analysis was re-employed using pork price as the variable to be explained. (Appendix Table 1). The analysis yielded the following functions:

1. Y_p 168.6763 $-$ 1.3055X_1 $-$ .4901X_2 $+$ .0080X_3
   (R_y = .915)

where:

Y_p = United States average retail price of pork, cents per pound.
X_1 = United States average per capita pork consumption, pounds.
X_2 = United States average per capita beef consumption, pounds.
X_3 = Unitd States average per capita disposable income, dollars.

All variables for the equation have been determined. Disposable income for 1975 was established at $2,916. Pork and beef consumption

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[14] Initial estimates were provided by Dr. G. G. Judge, Department of Agricultural Economics, University of Illinois, Urbana.

[15] "1960 Supplement to Economic Indicators," Office of Statistical Standards Bureau of the Budget, U.S. Government Printing Office, Washington, D. C., 1960. Consumer price index in 1947 was 95.5 and in 1960, 126.5. The Illinois estimates were therefore multiplied by $\frac{126.5}{95.5}$, or 1.325.

[16] The use of rail rates as an indicator of truck rates is not a matter of choosing among alternatives. The availability of published rail rates is largely a by-product of regulation. Meat shipments by truck are also regulated but data of broad applicability are not readily available over a period of years. Livestock shipments by truck are not regulated, and rates are not published. The investigators are somewhat encouraged by the thought that competition between regulated railroads and regulated or unregulated trucks will cause changes in truck rates to follow changes in rail rates rather closely.

in 1975 were estimated at 53.83 pounds per capita and 114.26 pounds per capita, respectively. Incorporating these variables in the equation resulted in an estimated 1975 average retail pork price of 65.83 cents per pound.

The 1975 average United States retail price of beef (all grades), which is consistent with the estimated pork consumption, beef consumption, income, and pork price, was estimated to be 92.88 cents per pound.

The use of estimating equations based on historic data to predict 1975 values assumes that the coefficients of the equations will not change greatly over time. These assumptions seem to be substantiated by studies that have employed such variables over time.[17]

SHIPMENT PATTERNS FOR 1975

Three 29-region models were employed in the estimation of 1975 shipment patterns for hogs and pork. The analysis was conducted in a manner identical to that employed in developing the 1960 models. No regional changes were made beyond the disaggregation of Region 17 (Iowa, Illinois and Missouri). The discussion in this section deals with three models: (1) A transportation model describing a least cost shipment pattern for hogs moving from production to slaughter, and two spatial equilibrium models describing optimum (2) slaughter-consumption and (3) production-consumption shipments. Regional identities and basic inputs are summarized in Table 6.

Production-Slaughter Shipments - Transportation Model

An optimum shipment pattern for live hogs moving from surplus production regions to surplus slaughter regions under estimated 1975 conditions is presented in Table 7 and Chart E. There are seven surplus regions and twenty-two deficit regions. Minor regional rearrangements from the 1960 pattern are apparent. Due to an expansion of the slaughter industry in Western Ohio, Region 11 is no longer a net exporter of live hogs. Arkansas and Louisiana (Region 18) have also become net importers of live hogs due to a decline in regional production relative to regional slaughter. Hogs imported into Western Ohio (Region 11) are purchased in Regions 13 and 17b (Indiana and Illinois). Supplementary hogs required by the slaughter industry in Eastern Ohio (Region 10) are obtained from Indiana and from Wisconsin and Minnesota (Region 16). Neither Eastern nor Western Ohio have any favorable alternatives to these procurement sources.

Slaughter-Consumption Shipments - Spatial Equilibrium Model

An optimum shipment pattern for net movement of pork from surplus slaughter regions to surplus consumption regions is presented in Table 8 and Chart F. The arrangement of surplus and deficit regions is identical to the arrangement existing in 1960 with one exception ex-

[17]Breimyer, H. F., "Demand and Prices for Meat," Economic Research Service, United States Department of Agriculture, Technical Bulletin Number 1253, December, 1961. See also, Kelly, P. L., et. al., **op. cit.**, and Judge, G. G. and T. D. Wallace, **op. cit.**

Table 6 — Estimated Hog Production, Total Hog Slaughter, Population, and Disposable Income, 29 Regions, United States, 1975

Region	State	Basing Point	Hog Production[1]	Hog Slaughter[2]	Population[3]	Per Capita Disposable Income[4]
			(000 lbs.)	(000 lbs.)	(000)	(dollars)
1	Me., N.H., Vt., Mass., Conn, R.I.	Boston	38,834	47,463	13,031	3.312
2	N.Y. (N.Y.C. excluded)	Syracuse	25,889	321,468	7,244	3,541
3	N.J., N.Y.C., Phila.	Perth Amboy	40,991	888,351	26,834	3,541
4	Md., D.C., Del.	Baltimore	45,306	157,492	6,337	3,278
5	Pa. (Phila. excluded)	Harrisburg	92,769	345,681	8,650	2,925
6	Virginia	Richmond	155,334	806,875	5,038	2,363
7	West Virginia	Charleston	17,259	23,732	1,562	2.207
8	N.C., S.C., Ga.	Columbia	1,277,192	960,052	12,622	2,016
9	Florida	Tampa	88,454	172,594	9,508	3,117
10	Eastern Ohio	Cleveland	148,862	229,981	7,234	3,171
11	Western Ohio	Dayton	595,448	919,924	5,966	3,197
12	Michigan	Lansing	243,788	241,631	10,639	2,828
13	Indiana	Indianapolis	2,178,994	1,641,796	6,107	2,613
14	Kentucky, Tenn.	Bowling Green	910,431	1,404,480	7,068	2,270
15	Alabama, Miss.	Birmingham	414,225	343,030	5,761	2,031
16	Wisconsin, Minn.	St. Paul	2,642,839	2,336,485	9,674	2,500
17a	Iowa	Des Moines	5,406,493	4,012,799	2,978	2,139
17b	Illinois	Peoria	3,210,241	960,052	13,328	3,553
17c	Missouri	Jefferson City	1,175,794	1,520,981	5,135	2,935
18	Arkansas, Louisiana	Monroe	79,825	101,399	5,919	2,167
19	North Dakota, South Dakota	Aberdeen	938,478	595,448	1,363	1,505
20	Nebraska, Kansas	Grand Island	1,316,026	2,047,390	4,084	2,264
21	Oklahoma, Texas	Ft. Worth	211,427	455,216	15,794	2,639
22	Mont., Wyo., Idaho	Billings	32,361	146,705	2,058	1,914
23	Colorado	Denver	43,148	81,982	2,614	2,502
24	New Mexico, Arizona	Gallup	17,259	88,454	4,149	2,689
25	Washington, Oregon	Portland	81,982	286,937	5,981	2,351
26	Nevada, Utah	Salt Lake City	12,945	92,769	1,760	2,469
27	California	Fresno	131,603	343,030	25,619	3,421
United States			21,574,197	21,574,197	234,057	2,916

[1]U. S. Total derived by conversion (171.233 percent) from estimated pork consumption. Regional values derived from percentage distribution presented in Table 5.
[2]U. S. Total derived by conversion (171.233 percent) from estimated pork consumption. Regional values derived from percentage distribution presented in Table 5.
[3]"The Big Growth Ahead," The Kiplinger Washington Editors, 1729 H St., N. W. Washingotn D.C., Special enclosure, issue of December 23, 1961.
[4]Provided by G. G. Judge, Dept. of Agr. Econ., Univ. of Ill., Adjustments for selected regions based on "Survey of Buying Power," Sales Management Magazine of Marketing, May 10, 1961.

Table 7 — TRANSPORTATION MODEL, PRODUCTION TO SLAUGHTER: Optimum Shipment Pattern for Slaughter Hogs, Surplus Production Regions to Surplus Slaughter Regions, 29-Region Model, United States, 1975 (Transportation cost — $63,327,881.60)

Deficit Production Regions[1]	Surplus Hog Production Regions and Volume of Export								Total Destination Requirement[2]
	8	12	13	15	16	17a	17b	19	
1	- .49[3]	2,157	- .09	- .90	- .03	- .12	6,472	- .94	8,629
2	- .90	- .18	- .27	-1.22	- .21	- .10	295,579	- .91	295,579
3	- .45	- .19	- .04	- .86	- .09	- .09	847,360	- .99	847,360
4	- .36	- .19	- .02	- .77	- .07	- .14	112,186	- .98	112,186
5	- .53	- .18	- .03	- .85	- .09	- .14	252,912	- .99	252,912
6	304,195	-1.23	206,249	- .48	- .13	- .18	141,097	-1.03	651,541
7	- .50	- .15	6,473	- .64	- .17	- .28	- .01	-1.08	6,473
9	12,945	- .97	- .44	71,195	- .53	- .42	- .28	-1.51	84,140
10	-1.18	- .15	- .09	-1.19	2,159	.11	78,960	- .92	81,119
11	-1.23	- .37	324,476	-1.11	- .17	- .17	0.00	- .53	324,476
14	-1.04	- .76	- .12	- .50	- .22	- .02	494,049	-1.19	494,049
17c	-2.13	-1.37	- .73	-1.40	- .21	345,187	- .32	-1.02	345,187
18	- .87	-1.08	- .16	- .04	- .22	- .02	21,574	-1.12	21,574
20	-2.45	-1.47	-1.16	-1.98	77,665	653,699	- .55	- .26	731,364
21	-1.55	-1.42	- .91	- .93	- .13	243,789	- .41	.65	243,789
22	-2.83	-2.30	-1.55	-2.41	0.00	- .21	- .82	114,344	114,344
23	-2.39	-1.29	-1.14	-1.90	38,834	- .01	- .58	- .35	38,834
24	-1.99	-1.65	-1.20	-1.48	- .29	71,195	- .47	- .52	71,195
25	-2.85	-1.89	-1.60	-2.36	0.00	- .31	- .90	204,955	204,955
26	-2.49	-2.43	-1.24	-1.99	- .02	79,824	- .59	- .02	79,824
27	-2.39	-1.54	-1.23	-1.31	187,696	- .12	- .70	23,731	211,427
Total Exports[2]	317,140	2,157	537,198	71,195	306,354	1,393,694	2,250,189	343,030	5,220,957

[1]These may be otherwise regarded as surplus slaughter regions in relation to local hog production
[2]Thousands of pounds liveweight.
[3]Dollars per hundredweight or cents per pound.

Source: Original data

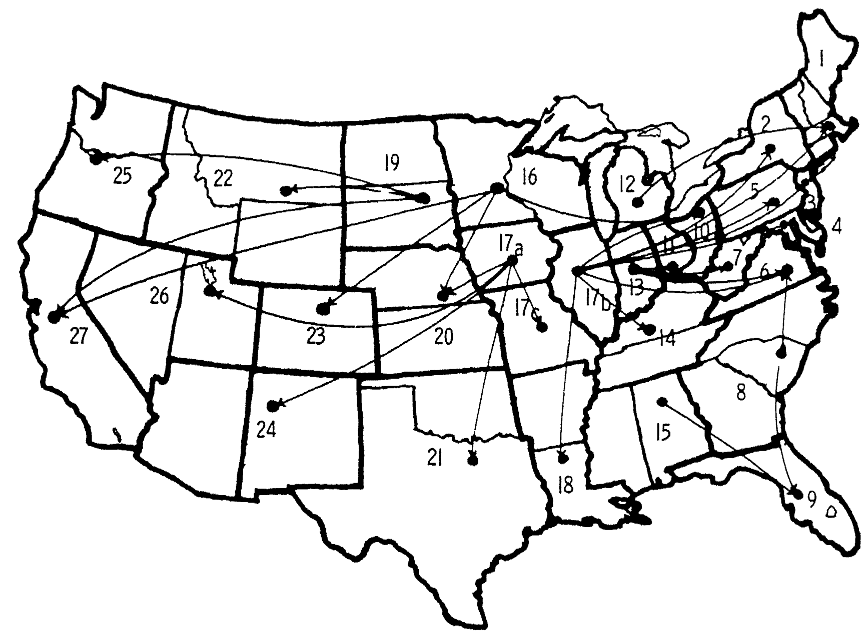

CHART E—Transportation Model, Production to Slaughter: Optimum Shipment Pattern for Slaughter Hogs, Surplus Production Regions to Surplus Slaughter Regions, 29—Region Model, United States, 1975.

Source: Table 7

posed by disaggregation of Region 17 (Iowa, Illinois, and Missouri, in the 1960 analysis). Iowa and Missouri are exporters of pork, but due to decentralization of Illinois slaughter and consequent closing of many Chicago packing plants, Illinois appears as a net importer of pork in 1975.[18]

Most surplus regions increased greatly in export capacity over 1960 levels although total pork consumption changed little. This may indicate that slaughter activity will continue to concentrate in regions characterized by decentralization of slaughter activity. For example, increases in slaughter activity are apparent in Virginia, Western Ohio, Indiana, Kentucky and Tennessee, Iowa and Missouri, and Nebraska and Kansas. However. Minnesota, Wisconsin, North Dakota and South Dakota do not appear to share in the trend.

Equilibrium conditions in 1975 may result in increased trade between Western Ohio (Region 11) and Eastern Ohio (Region 10). The

[18]Illinois slaughter declined rapidly between 1947 and 1961. A single log function modified this trend noticeably in the estimation of 1975 slaughter levels. Nevertheless, if one assumes that the decline was due to the closing of Chicago packing houses, and if the trend in Chicago itself was essentially completed by 1961, then the aggregate Illinois trend is overemphasized. The data suggest emphatically, however, that Illinois may represent one of the most favorable areas of the United States for new slaughter locations in the next ten years.

Table 8 — SPATIAL EQUILIBRIUM, SLAUGHTER TO CONSUMPTION: Optimum Shipment Pattern for Pork, Surplus Slaughter Regions to Surplus Consumption Regions, 29-Region Model, United States, 1975
(Transportation cost — $127,190,995.90)

Deficit Slaughter Region[1]	Surplus Pork Slaughter Regions and Volume of Export									Total Destination Requirements[3]
	6	11	13	14	16	17a	17c	19	20	
1	- .45[3]	- .33	- .31	- .71	- .18	611,557	- .40	-1.05	-1.00	611,557
2	- .62	- .27	- .22	- .79	- .14	151,065	- .22	- .85	- .97	151,065
3	- .12	- .02	229,575	- .42	- .02	503,329	- .91	- .91	- .83	732,904
4	168,530	- .01	54,425	- .35	- .06	- .10	- .19	- .97	- .90	222,955
5	- .21	48,370	213,220	- .43	- .06	- .08	- .17	- .97	- .87	261,590
7	- .88	82,617	- .00	- .34	- .26	- .32	- .21	-1.19	- .98	82,615
8	- .37	- .15	107,661	40	- .17	- .14	132,080	-1.06	- .90	239,781
9	- .86	- .45	- .27	384,856	- .25	- .13	- .03	-1.12	- .85	384,856
10	-1.19	99,441	- .01	- .58	138,095	- .06	- .26	- .95	- .85	236,536
12	-1.86	- .32	- .14	- .87	445,799	- .04	- .38	- .97	- .89	445,799
15	-1.63	- .68	- .39	- .06	- .47	- .29	166,405	-1.39	-1.01	166,405
17b	-2.72	-1.06	- .62	-1.15	- .10	74,104	- .32	-1.15	- .88	74,104
18	-2.30	-1.08	- .69	- .47	- .53	- .29	308,501	-1.14	- .74	308,501
21	-2.69	-1.53	-1.10	- .94	- .28	633,612	- .16	- .86	- .19	633,612
22	-3.62	-2.27	-1.88	-2.38	- .12	- .28	-1.09	47,737	- .36	47,737
23	-3.60	-2.06	-1.64	-2.02	- .37	- .25	-1.02	- .72	105,528	105,528
24	-2.98	-1.57	-1.38	-1.09	- .42	180,368	-1.18	- .63	- .05	180,368
25	-3.16	-1.96	-1.61	-1.91	- .00	- .29	-1.10	185,577	- .23	185,577
26	-3.39	-2.02	-1.64	-1.99	- .29	- .19	-1.05	- .22	48,755	48,755
27	-2.83	-1.60	-1.25	-1.57	202,978	- .12	- .37	18,484	787,989	1,009,451
Total Exports[2]	168,530	230,426	604,881	384,896	785,872	2,154,035	606,986	251,798	942 272	6 129,696

[1]These may be otherwise regarded as surplus consumption regions in relation to local pork slaughter.
[2]Thousands of pounds edible pork, based on a conversion (58.3998%) from liveweight.
[3]Dollars per hundredweight or cents per pound.

Source: Original data

CHART F—Spatial Equilibrium, Slaughter to Consumption: Optimum Shipment Pattern for Pork, Surplus Regions to Surplus Consumption Regions, 29-Region Model United States, 1975.

Source: Table 8

market for Western Ohio pork generally may have expanded, with shipments to Pennsylvania (Region 5) and West Virginia (Region 7) perhaps more than doubled, and large shipments to Eastern Ohio. Larger indirect costs,[19] moreover, suggest that the competitive position of Western Ohio in the markets it supplies may be somewhat improved (over 1960 conditions) relative to other Corn Belt suppliers. Similarly, competition from Southern exporting regions may be more keenly felt resulting in somewhat of a shift of Western Ohio export emphasis away from the Southeast and more toward the Northeast.

Production-Consumption Shipments - Spatial Equilibrium Model

An optimum pattern for shipment of production-oriented slaughter to surplus consumption regions is presented in Table 9 and Chart G. The total transportation bill of $161.6 million represents a saving of $29 million over the aggregate transportation bills of the preceeding two models. The arrangement of surplus and deficit regions is identical to that prescribed in the comparable 1960 model.

Should the trend toward production-oriented slaughter continue, Western Ohio would be much less significant as an exporter of pork than was indicated by the parallel 1960 model. Ohio's competitive posi-

[19] Interregional value differences less interregional transportation costs.

Table 9 — SPATIAL EQUILIBRIUM, PRODUCTION TO COSUMPTION: Optimum Shipment Pattern for Pork, Surplus Production Regions to Surplus Consumption Regions, 29-Region Model, United States, 1975 (Transortation cost — $161,570,642.50)

Deficit Production Regions[1]	Surplus Pork Production Regions and Volume of Export									Total Destination Requirements[2]
	11	13	14	16	17a	17b	17c	19	20	
1	- .33[3]	- .35	- .86	- .20	616,882	- .26	- .61	-1.07	-1.02	616,882
2	- .32	- .27	- .94	- .17	323,835	- .01	- .43	- .87	.99	323,835
3	.06	- .04	- .57	- .04	1.028,804	199.549	.30	- .93	- .85	1,228,353
4	.01	288,433	- .46	- .04	- .06	- .02	- .44	- .95	- .88	288,433
5	- .00	320,687	- .54	- .04	- .04	88,542	- .34	- .95	- .85	409,229
6	- .06	209,620	- .17	- .11	- .10	- .03	- .31	-1.00	- .86	209,620
7	40.968	45,417	- .45	- .24	- .28	- .08	- .58	-1.17	- .96	86,385
8	- .15	54,483	- .09	- .15	- .10	- .04	- .17	-1.04	- .88	54,483
9	- .34	- .16	58,537	- .12	- .01	371,676	- .09	-1 02	- .72	433,213
10	- .03	- .04	- .72	- .01	- .05	284,010	- .46	- .96	- .86	284,010
12	- .34	- .16	-1.00	155,379	- .02	289,266	- .57	- .97	- .89	444,645
15	- .51	- .62	38,464	- .28	- .08	- .06	85,655	-1.20	- .82	124.119
18	- .91	- .92	- .41	- .34	- .08	- .15	320,373	-1.24	- .55	320.373
21	-1.57	-1.14	-1.09	- .30	776.327	- .58	- .37	- .98	.21	776.327
22	-2.29	-1.90	-2.31	- .12	- .26	-1.10	- .28	114.527	- .36	114.527
23	2.08	-1.66	-2.15	- .37	- .23	-1.04	-1.21	- .72	128.227	128 227
24	-1.61	-1.42	-1.20	.44	222,037	- .64	- .39	- .65	- .07	222.037
25	-1.98	-1.63	-2.04	- .00	- .27	- .97	-1.31	305,313	- .23	305.313
26	-2.04	-1.66	-2.12	- .29	- .17	- .95	-1.24	- .22	95,384	95,384
27	-1.52	-1.27	-1.70	809,335	- .06	- .75	- .56	32,277	291,517	1,133.129
Total Exports[2]	40,968	918.640	97,001	964,714	2.967,885	1.236,043	406,028	452,117	515.128	7.598 524

[1]These may be otherwise regarded as surplus consumption regions in relation to local pork production and slaughter.
[2]Thousands of pounds edible pork, based on a conversion (58 3998%) from liveweight
[3]Dollars per hundredweight or cents per pound.

Source: Original data

tion as an exporter to the market it would retain (West Virginia), however, would be comparatively stronger than was indicated by the 1960 pattern. Also, it appears that Eastern Ohio would meet its needs for supplementary pork with shipments from Illinois rather than Wisconsin and Minnesota, although pork could be obtained from Wisconsin-Minnesota (Region 16) for little additional cost.

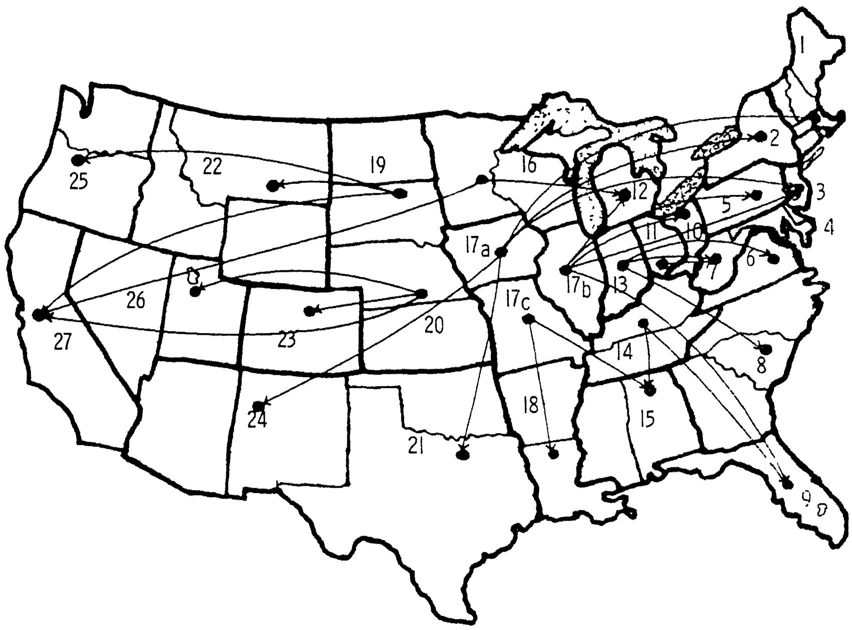

CHART G—Spatial Equilibrium, Production to Consumption: Optimum Shipment Pattern for Pork, Surplus Production Regions to Surplus Consumption Regions, 29-Region Model, United States, 1975.

Source: Table 9

INTERREGIONAL IMPLICATIONS, 1960-1975

Evaluation of implications of the foregoing analysis is tempered by four considerations: (1) The analysis seeks to optimize interregional trade activity in the hog-pork sector of the livestock-meat economy, while the industry seeks to optimize aggregate activity at the expense of single sectors, if necessary. But a determination of the extent of diseconomy in a single sector is a component of decision-making for aggregate activity. The analysis proposes optimum standards which otherwise might not be established for the hog-pork sector separately. (2) The analysis seeks to determine optimum activity for a single year while the industry seeks to optimize the long-run, at the expense of a single year, if necessary. Optimum in the long-run, however, is the aggregate performance of a series of single years. An evaluation of single year performance is a component of long-run decision-making. (3) Limits of the results are found in limits of the information introduced into the analysis. But the models are structured to incorporate the information that ordinarily is employed in developing management decisions, and (4) Projections were based upon present trends. The 1975 solutions, therefore, may be interpreted as conditions responding to continuing trends or as conditions indicating impending changes in present trends.

Implications to the Industry

Some basic changes that the livestock-meat industry may anticipate for the hog-pork sector are evident in Table 10. Despite the persistent decline in per capita pork consumption. the industry may enjoy a modest (8 percent) expansion due to a rapid rate of population increase.[20] The greatest population growth is expected in the Mid-Atlantic states, in Florida and in the West and Southwest. These areas are not associated with expansion of slaughter activity in comparable proportions although some increases may be anticipated in Florida and the Southwest. Projection of present trends indicates that Virginia, Western Ohio and New Mexico and Arizona may experience a more rapid increase in slaughter activity than elsewhere in the United States. The basis for this increase in these regions, and in other regions, is not found in a parallel increase in production. Generally the level of slaughter anticipated in areas of increased activity will exceed regional production potentials by 1975 (Table 11). This may mean that the present rapid rate of slaughter relocation toward presumed sources of supply may occur at a slower rate than present trends indicate. The possibility seems to be confirmed by total transportation bills derived from the 1960 and 1975 analyses. The 1960 production-consumption shipment pattern (Table 4) revealed a potential 12 percent decrease in transportation costs over aggregate production-slaughter-consumption shipments in 1960. The parallel shipment pattern for 1975 (Table 9), however, indicated that production-oriented slaughter would represent a 15 per-

[20]Indeed, whether the figures represent any increase at all depends upon comparative positions on a production cycle in the two periods being compared. U.S. hog production has been greater in other years than it was in 1960.

Table 10 — Hog Production, Hog Slaughter, Population and Per Capita Disposable Income, 27 Regions, United States, 1975 as a Percent of 1960

Region	Basing Point	Hog Production	Hog Slaughter	Population	Per Capita Disposable Income
1	Boston, Mass	71.21	31.79	123.99	153.26
2	Syracuse, N.Y.	54.07	138.01	119.00	152.56
3	Perth Amboy, N.J.	128.87	116.50	127.15	144.83
4	Baltimore, Md.	70.56	78.35	146.99	142.83
5	Harrisburg, Pa.	55.15	100.83	123.99	149.54
6	Richmond, Va.	79.88	154.84	126.99	142.95
7	Charleston, W. Va.	50.16	89.73	83.98	142.94
8	Columbia, S.C.	123.01	99.18	116.00	142.78
9	Tampa, Fla.	92.68	122.65	192.00	179.14
10	Cleveland, Ohio	82.91	50.02	136.00	152.89
11	Dayton, Ohio	80.44	159.82	135.99	152.89
12	Lansing, Mich.	91.09	64.65	135.99	136.42
13	Indianapolis, Ind.	123.75	131.28	130.99	134.21
14	Bowling Green, Ky.	108.24	137.99	107.01	161.91
15	Birmingham, Ala.	87.84	82.34	105.82	158.79
16	St. Paul, Minn.	122.15	103.62	131.33	133.83
17	Burlington, Iowa	112.89	95.59	124.95	132.96
18	Monroe, Louisiana	36.98	61.19	117.37	153.58
19	Aberdeen, S. Dakota	127.99	98.49	103.97	108.04
20	Grand Island, Neb.	100.98	115.68	113.76	124.39
21	Ft. Worth, Texas	46.71	71.81	132.63	153.07
22	Billings, Montana	29.87	117.39	123.08	107.23
23	Denver, Colorado	64.42	51.73	149.03	127.52
24	Gallup, New Mexico	71.00	144.16	184.15	158.74
25	Portland, Oregon	79.47	99.49	129.40	116.10
26	Salt Lake City, Utah	59.02	124.53	149.66	130.70
27	Fresno, California	136.44	88.41	163.00	142.36
United States		108.12	108.12	131.15	135.65

Source: Tables 1 and 6.

cent transportation cost saving over aggregate production-slaughter-consumption shipments. This suggests that a continuation of current patterns of regional relocation in slaughter activity could result in over-expansion relative to regional supplies in areas apparently desirable by present standards. Some interregional changes seem justified on the basis of present trends; others appear to suggest impending changes in present trends.

Interregional Changes in Production, Slaughter and Consumption

The propensity of the packing industry to locate close to sources of supply is based in part on a desire to minimize total transportation charges.[21] That production-oriented slaughter serves to minimize transport costs is demonstrated in production-consumption shipment patterns in both the 1960 and the 1975 analyses. On this basis, regions that are low in slaughter capacity relative to both hog production and pork consumption appear to offer favorable opportunities for increased slaughter

[21]Many considerations other than transportation costs enter into packing plant location decisions. Livestock quantity and quality is one of them. Others include the comparative costs and efficiencies of existing plants and proposed plants; comparative labor costs and union contracts; state tax laws along with apparent legislative attitudes; the availability of necessary facilities, particularly water; and the market value of the existing plant.

Table 11 — **Slaughter Hog Production and Total Hog Slaughter as a Percent of Pork Consumption, 27 and 29 Regions, United States, 1960 and 1975.**

Regions	Estimated 1960 Levels Consumption	Slaughter[1]	Production[1]	Estimated 1975 Levels Consumption	Slaughter[1]	Production[1]
1	100.0	12.70	4.64	100.0	3.95	3.23
2	100.0	32.22	7.03	100.0	48.14	3.88
3	100.0	32.31	1.35	100.0	35.92	1.66
4	100.0	41.70	13.33	100.0	26.96	7.76
5	100.0	43.95	21.55	100.0	43.36	11.64
6	100.0	117.47	43.84	100.0	173.75	33.45
7	100.0	28.68	16.54	100.0	16.48	11.99
8	100.0	79.57	85.33	100.0	82.52	109.78
9	100.0	25.41	17.24	100.0	19.69	10.09
10	100.0	77.31	30.19	100.0	34.49	22.33
11	100.0	117.35	150.91	100.0	167.28	108.28
12	100.0	42.73	30.60	100.0	24.64	24.86
13	100.0	240.05	337.79	100.0	291.66	387.09
14	100.0	137.82	113.89	100.0	215.58	139.75
15	100.0	68.44	77.47	100.0	64.60	78.01
16	100.0	273.78	262.70	100.0	262.03	296.38
17	100.0	310.45	462.11	——	——	——
17a	——	——	——	100.0	1461.87	1969.60
17b	——	——	——	100.0	78.15	261.31
17c	——	——	——	100.0	321.34	248.41
18	100.0	29.39	38.28	100.0	18.59	14.63
19	100.0	412.44	500.22	100.0	473.95	746.99
20	100.0	440.92	324.66	100.0	543.88	349.60
21	100.0	47.61	34.00	100.0	31.27	14.52
22	100.0	66.85	57.96	100.0	77.34	17.06
23	100.0	80.81	34.15	100.0	34.02	17.91
24	100.0	24.36	9.65	100.0	23.13	4.51
25	100.0	55.81	19.96	100.0	52.05	14.87
26	100.0	56.65	16.68	100.0	57.18	7.98
27	100.0	22.08	5.49	100.0	14.53	5.57

[1]Retail-equivalent weight

Source: Computations in retail-equivalent weights based on Tables 1 and 6.

activity since both hog and pork shipment distances are minimized. North Carolina, South Carolina and Georgia (Region 8), Alabama and Mississippi (Region 15) and Arkansas and Louisiana (Region 18) displayed these characteristics in 1960. But estimates of 1975 slaughter disclosed increases in none of these regions. Slaughter remained unchanged in Region 8 and declined in Regions 15 and 18.

By and large, packing plant relocation is a characteristic of national and large regional firms. Small firms cease operations at one site without relocating elsewhere. While the patterns displayed by developing conditions in Regions 8 and 18 may reflect a certain unawareness of potential by large firms, it may also reflect other factors not related to transportation cost advantages. Undesirable animal quality attributes would explain an apparent lack of packer enthusiasm for location in some southern regions. Parasites and animal disease would prevent a prohibitively high percentage of pork from passing Federal inspection and entering interstate trade. Such conditions could promote interstate shipment of hogs and intrastate distribution of pork from plants not subject to Federal inspection. A pattern of consumer-oriented plant locations might emerge under such conditions. The projection of present trends does indicate that opportunities normally associated with surplus hog production relative to local slaughter capacity will not be thoroughly exploited in the Southeast by 1975.

Southern, western and northern Corn Belt fringe areas present a different pattern. In 1960 Kentucky and Tennessee (Region 14), Wisconsin and Minnesota (Region 16) and Nebraska and Kansas (Region 20) all displayed slaughter capacity in excess of production levels, and production levels higher than consumption levels (Table 11). Under these conditions slaughterers were obliged to import hogs from other regions and also enter interregional trade in the distribution of pork. Implications to slaughter capacity exceeding regional production and consumption are found in comparative prices for hogs and for pork relative to other regions. For example, equilibrium conditions in 1960 found Region 16 packers paying $0.10 per hundredweight more for hogs than prices prevailing in the base region (Region 11, Western Ohio), but realizing $1.02 less per hundredweight than the base region in pork prices received (Table 12). In contrast Arkansas and Louisiana packers (Region 18) bought hogs at $0.32 less than base region price and sold pork at $0.83 more than base region price. Competitive conditions therefore appear to be more rigorous in areas where slaughter exceeds local levels of production and consumption. Such conditions were charactristic of the Corn Belt fringe areas in 1960 and suggested that, on the basis of price differentials, the climate for further increases in packer activity might be less favorable than in southern regions. Projected trends disclosed, however, that increases in both production and slaughter generally may be anticipated in these Corn Belt fringe areas with slaughter levels continuing to exceed local production. The exception to the generalization was the Wisconsin-Minnesota region, which displayed unfavorable price relationships relative to the base region in 1960. The 1975 shipment patterns indicated a slight increase in slaughter activity in the area, accompanied by an increase in hog production and a consequent surplus of slaughter hogs. The resulting pattern of price differentials was more amenable to slaughter location and interregional competition in 1975 than in 1960.

Other regions displaying conditions favorable to increased slaughter activity in the 1960 analysis were Western Ohio (Region 11), Indiana (Region 13), Iowa, Illinois and Missouri (Region 17), and North and South Dakota (Region 19). The 1975 analysis indicated that all of these regions may follow this anticipated pattern and generally the extent of slaughter growth still may not utilize production existing in the respective regions. There were two exceptions: (1) Projections indicated a decrease in Illinois slaughter due principally to post-war closing of many Chicago plants. Consequently, Illinois appears to be one of the most desirable states for slaughter location in the U.S. over the next decade. (2) Continuation of post-war rates of increase in slaughter in Western Ohio and Missouri can result in slaughter levels exceeding production levels in 1975 by substantial proportions.

The effect on pork price and consumption of these interregional shifts in population, hog production and total slaughter is presented in Tables 13 and 14. The pattern of trade toward which the industry is

Table 12 — Cents Per Pound Live Hog Price and Retail Pork Price Differentials Between Regions, Transportation and Spatial Equilibrium Solutions, 27- and 29-Region Models, United States, 1960 and 1975
(Based on Dayton, Ohio, Region 11)

Region[1]	Transportation Models						Spatial Equilibrium Models			
	Production to Slaughter Model		Slaughter to Consumption Model		Production to Consumption Model		Slaughter to Consumption Model		Production to Consumption Model	
	1960	1975	1960	1975	1960	1975	1960	1975	1960	1975
1	1.28	1.34	1.53	1.62	1.55	1.58	1.53	1.62	1.55	1.58
2	.97	.80	1.23	1.31	1.23	1.27	1.23	1.33	1.23	1.27
3	1.02	.98	1.28	1.49	1.28	1.45	1.28	1.49	1.28	1.45
4	.82	.77	1.07	1.23	1.07	1.23	1.07	1.23	1.07	1.23
5	.79	.72	1.04	1.19	1.04	1.19	1.04	1.19	1.04	1.19
6	.90	.88	.57	.66	1.16	1.33	.57	.66	1.16	1.33
7	.43	.33	.60	.69	.60	.69	.60	.69	.60	.69
8	.23	.09	1.15	1.23	1.15	.58	1.15	1.32	1.15	1.32
9	.69	1.11	1.60	1.69	1.60	1.89	1.60	1.78	1.60	1.89
10	.36	.22	.53	.65	.55	.62	.53	.65	.55	.62
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
12	.15	- .18	.29	.42	.29	.40	.29	.42	.29	.40
13	- .15	- .35	- .19	- .22	- .19	- .22	- .29	- .22	- .29	- .22
14	.26	.12	.01	- .14	.08	.06	.08	- .05	.08	.06
15	- .26	.00	.74	.64	.81	.81	.81	.73	.81	.90
16	.10	-1.21	-1.02	-1.13	-1.00	-1.15	-1.02	-1.13	-1.00	-1.15
17	- .56	——	- .65	——	- .65	——	- .65	——	- .65	——
17a	——	- .97	——	- .92	——	- .96	——	- .92	——	- .96
17b	——	- .70	——	- .13	——	- .57	——	- .13	——	- .57
17c	——	- .36	——	- .80	——	- .63	——	- .71	——	- .54
18	- .32	.66	.83	.71	.83	.88	.83	.80	.83	.97
19	.09	- .81	- .66	- .71	- .64	- .73	- .66	- .71	- .64	- .73
20	.11	- .31	- .59	- .63	- .57	- .65	- .59	- .63	- .57	- .65
21	.29	.23	.63	.83	.63	.79	.63	.83	.63	.79
22	1.02	.28	.73	.89	.75	.87	.73	.89	.75	.87
23	.60	.15	.38	.48	.40	.46	.38	.48	.40	.46
24	1.19	.75	1.33	1.53	1.35	1.49	1.33	1.53	1.35	1.49
25	2.00	1.43	2.01	2.36	2.03	2.34	2.01	2.36	2.03	2 34
26	1.08	.73	1.09	1.30	1.11	1.28	1.09	1.30	1.11	1.28
27	1.83	1.62	2.19	2.65	2.21	2.54	2.19	2.56	2.21	2.54

[1]Regions identified in Table 6.

Source: Original Data.

Table 13 — Per Capita Pork Consumption and Retail Pork Price Per Pound 27- and 29-Region Spatial Equilibrium Solutions, United States, 1960 and 1975

Region[1]	Slaughter to Consumption Models				Production to Consumption Models			
	Per Capita Consumption (lbs.)		Price Per Pound (cts.)		Per Capita Consumption (lbs.)		Price Per Pound (cts.)	
	1960	1975	1960	1975	1960	1975	1960	1975
1	62.81	49.06	57.71	66.48	62.81	49.08	57.71	66.45
2	61.27	46.77	57.41	66.17	61.28	46.79	57.39	66.14
3	59.88	46.65	57.46	66.35	59.89	46.67	57.44	66.32
4	61.66	19.70	57.25	66.09	61.67	49.69	57.23	66.10
5	65.38	53.58	57.22	66.05	65.40	53.57	57.20	66.06
6	69.01	60.08	56.75	65.52	68.62	59.61	57.32	66.20
7	70.18	61.76	56.78	65.55	70.20	61.76	56.76	65.56
8	71.25	63.42	56.33	66.18	71.25	63.41	56.31	66.19
9	67.36	51.08	57.78	66.64	67.37	51.00	57.76	66.76
10	64.45	51.26	56.71	65.51	64.44	51.28	56.71	65.49
11	64.62	51.43	56.18	64.86	64.65	51.42	56.16	64.87
12	64.62	55.17	56.47	65.28	64.63	55.18	56.45	65.27
13	66.33	57.95	55.99	64.64	66.34	57.95	55.92	64.65
14	72.09	61.59	56.26	64.81	72.11	61.50	56.24	64.93
15	72.93	63.66	56.99	65.59	72.95	63.54	56.97	65.77
16	67.76	59.81	55.16	63.73	67.77	59.82	55.16	63.72
17	64.28	——	55.53	——	64.30	——	55.51	——
17a	——	63.61	——	63.94	——	63.63	——	63.91
17b	——	47.63	——	64.73	——	47.92	——	64.30
17c	——	54.77	——	64.15	——	54.65	——	64.33
18	71.47	62.13	57.01	65.66	71.49	62.00	56.99	65.84
19	72.70	70.39	55.52	64.15	72.71	70.40	55.52	64.14
20	67.98	62.05	55.59	64.23	67.99	62.05	55.59	64.22
21	68.00	56.95	56.81	65.69	68.20	56.97	56.79	65.66
22	67.46	64.83	56.91	65.75	67.46	64.83	56.91	65.74
23	65.77	58.69	56.56	65.34	65.77	58.69	56.56	65.33
24	68.05	55.92	57.51	66.39	68.04	55.95	57.51	66.36
25	63.96	59.05	58.19	67.22	63.96	59.05	58.19	67.21
26	66.07	58.48	57.27	66.16	66.09	58.49	57.27	66.15
27	59.71	47.22	58.37	67.42	59.71	47.23	58.37	67.41

[1]Regions identified in Table 6.
Source: Original data.

developing could, by 1975, result in a very uniform distribution of regional pork prices in the national market area. The regional price pattern would be similar to that existing in 1960, but would display less interregional variation (Table 14). The effect of interregional changes in production, slaughter, population and disposable income levels, however, is reflected in changing patterns of per capita pork consumption. While decreases in per capita consumption may be anticipated in all regions (Table 13), there also may be variations among regions relative to the base region (Table 14). Mid-Atlantic and New England states, Florida, and California, indicated per capita consumption lower than the base region in both 1960 and 1975 but the pattern was accentuated in the latter period. High per capita consumption in both periods was apparent in the Southeast, the central Corn Belt, and Corn Belt fringe areas. These areas also generally displayed the greatest increase in per capita consumption from 1960 to 1975.

The consumption pattern is of course related to the relative growth or decline of slaughter activity in the various regions and to the cost of importing pork into surplus consumption regions. Transportation adds to the cost of the commodity relative to exporting regions and per

Table 14 — Index of Per Capita Pork Consumption and Retail Pork Price Per Pound, 27- and 29-Region Spatial Equilibrium Solution, United States, 1960 and 1975.

(100 = Region 11, Dayton, Ohio)

Region[1]	Slaughter to Consumption Models				Production to Consumption Models			
	Per Capita Consumption (lbs)		Price Per Pounds (cts)		Per Capita Consumption (lbs)		Price Per Pound (cts)	
	1960	1975	1960	1975	1960	1975	1960	1975
1	97.2	95.4	102.7	102.2	97.2	95.4	102.8	102.4
2	94.8	90.9	102.2	102.0	94.8	91.0	102.2	102.0
3	92.7	90.7	102.3	102.3	92.6	90.8	102.3	102.2
4	95.4	96.6	101.9	101.9	95.4	96.6	101.9	101.9
5	101.2	104.2	101.9	101.8	101.2	104.2	101.9	101.8
6	106.8	116.8	101.0	101.0	106.1	115.9	102.1	102.1
7	108.6	120.1	101.1	101.0	108.6	120.1	101.1	101.1
8	110.3	123.3	102.0	102.0	110.2	123.3	103.0	102.0
9	104.2	99.3	102.8	102.7	104.2	99.2	102.0	102.9
10	99.7	99.7	100.9	101.0	99.7	99.7	101.0	101.0
11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12	100.0	107.3	101.5	100.6	99.9	107.3	100.5	100.6
13	102.6	112.7	99.7	99.7	102.6	112.7	99.6	99.7
14	111.6	119.8	100.1	99.9	111.5	119.6	100.1	100.1
15	112.9	123.8	101.4	101.1	112.8	123.6	101.4	104.1
16	104.9	116.3	98.2	98.3	104.8	116.3	98.2	98.2
17	99.5	—	98.8	—	99.5	—	98.8	—
17a	—	123.7	—	98.6	—	123.7	—	98.5
17b	—	92.6	—	99.8	—	93.2	—	99.1
17c	—	106.5	—	98.9	—	106.3	—	99.2
18	110.6	120.8	101.5	101.2	110.6	120.6	101.5	101.5
19	112.5	136.9	98.8	98.9	112.5	136.9	98.9	98.9
20	105.2	120.6	98.9	99.0	105.2	120.7	99.0	99.0
21	105.5	110.7	101.1	101.3	105.5	110.8	101.0	101.2
22	104.4	126.1	101.3	101.4	104.3	126.1	101.3	101.3
23	101.8	114.1	100.7	100.7	101.7	114.1	100.7	100.7
24	105.3	108.7	102.4	102.4	105.2	108.8	102.4	102.3
25	99.0	114.8	103.6	103.6	98.9	114.8	103.6	103.6
26	102.2	113.7	101.9	102.0	102.0	113.7	102.0	102.0
27	92.4	91.8	103.9	103.9	92.4	91.9	103.9	103.9

[1]Regions identified in Table 6

Source: Table 13.

capita consumption declines as price rises. Generally, however, regions evidencing lower or higher per capita consumption relative to the base region in 1960 showed the same relationship in 1975. Pork consumption in Florida (Region 9) and Washington and Oregon (Region 25) in 1975 deviated from the 1960 regional pattern. Between 1960 and 1975, Florida slaughter capacity increased 23 percent, but population rose 92 percent resulting in comparatively lower slaughter levels relative to consumption in the latter period (Tables 10 and 11). Also significant was the trend of per capita disposable income, which rose in Florida more than in any other region with a consequent depressing effect on pork consumption relative to competing meats. Similarly, population increases in Washington and Oregon were accompanied by decreases in production and unchanged slaughter levels. The region imported pork from North and South Dakota and hogs from Iowa and the Dakotas in 1960. The 1975 shipment patterns indicated that increased tonnages of pork would come from the Dakotas and increased shipments of hogs from the Dakotas or from Minnesota and Wisconsin, but no longer from Iowa.

Implications to the Ohio Hog-Pork Industry

In 1960, Ohio hog marketings plus farm slaughter (Regions 10 and 11) ranked eighth and total slaughter ranked seventh among 29 regions considered in this study. Expectations for 1975 include (1) a 17 percent decrease in hog production in Eastern Ohio and a 19 percent production decrease in Western Ohio, (2) a population increase in both regions of approximately 35 percent, (3) a decrease in slaughter activity in Eastern Ohio of 50 percent, and (4) an increase of 60 percent in slaughter activity in Western Ohio (Table 10). Hog production decreases in both Ohio regions perhaps reflect increasing urbanization and other factors associated with increases in population and industrial activity. But they also reflect shifts to and specialization in alternative agricultural enterprises (Table 15). For example, northwestern Ohio counties moved steadily into a cash grain type agriculture in the post World War II years, feeder livestock production increased in southeastern counties, dairy production expanded, largely in the northeastern counties, and truck crop and greenhouse production approximately doubled. The net effect to Ohio agriculture was a growth in cash receipts from farm sales, but a slight decline in farm sales of livestock and livestock products.

The decline in slaughter activity in Eastern Ohio between 1947 and 1961 was associated with the closing of plants in Cleveland and several interior points. Some of this decline occurred as a result of relocation of plants owned by national firms and some of the Cleveland closings were associated with declining cattle numbers on the Chicago Union Stockyards, a principal procurement source for Cleveland beef slaugh-

Table 15 — Cash Receipts From Farm Sales of Agricultural Products, Selected Commodities, Ohio, 1950 and 1960
(Thousands of dollars)

COMMODITY	1950	1960
Hogs	$194,581	$ 138,694
Cattle and Calves	120,318	131,348
Sheep and Wool	15,084	14,545
Dairy Products	185,685	210,320
Poultry and Eggs	105,139	93,572
Corn	51,498	99,512
Wheat	72,177	81,661
Soybeans	48,471	69,801
Oats	8,374	13,890
Truck Crops	16,806	29,059
Greenhouse and Nursery	30,722	58,476
All other	54,557	62,897
TOTAL	$903,412	$1,003,775

Source: "Ohio Farm Income, 1960," Department of Agricultural Economics, the Ohio State University, Departmental Series A. E. 325, October, 1961. Also, "Estimated Gross Cash Income to Ohio Farmers, 1950" Department of Agricultural Economics, the Ohio State University, Mimeograph Bulletin 228, October, 1951.

terers.[22] The rather spectacular projected rise in Western Ohio slaughter seems optimistic. Such increases, at a time when Western Ohio hog production may decline 19 percent, would greatly surpass the capacity of the region to supply hogs in necessary quantities. But regional boundaries are arbitrary. State lines moreover are irrelevant in the shipment of slaughter hogs. Examining the potential for slaughter location in Western Ohio in terms of the production potential of Region 13 (Indiana) reveals interesting possibilities. Increases in both production and slaughter are anticipated for Indiana. Hog production in both regions may exceed hog slaughter in both regions. Slaughter locations in Ohio would in effect exist on the eastern edge of the largest supply of slaughter hogs in the Eastern Corn Belt and on the western edge of large nearby consumer markets in heavily populated Ohio and adjacent regions. The 1975 analysis confirms these possibilities in terms of optimum trade patterns for Western Ohio slaughterers. The net effect of expected changes in Ohio would be to place Ohio tenth in production and seventh in slaughter among the 29 regions included in the analysis.

Western Ohio exhibits conditions characteristic of Corn Belt agriculture. Eastern Ohio displays characteristics paralleling those of neighboring eastern states. The analysis reveals different patterns of current and anticipated production and slaughter activity for the two Ohio areas. In 1960 Western Ohio produced slaughter hogs in excess of local slaughter needs while Eastern Ohio packers found it necessary to import additional hogs for slaughter. But under optimum conditions, trade did not develop between the two regions (Table 2). Western Ohio instead shipped slaughter hogs to Pennsylvania, New Jersey, New York City and Philadelphia, and to Maryland and Delaware. Alternative but not optimum markets existed in Virginia and West Virginia, but shipments into the areas would have occurred at a slight competitive disadvantage relative to other suppliers in Indiana. Eastern Ohio imported slaughter hogs from Region 17 (Iowa, Illinois and Missouri). Also, Eastern Ohio meat packing activity in 1960 lacked the capacity to meet local consumption requirements, and pork was imported from Wisconsin and Minnesota (Table 3). Western Ohio, was only a small exporter of pork and realized optimum markets in Pennsylvania and West Virginia, with favorable but not optimum alternatives in New Jersey, Maryland, Delaware and Eastern Ohio.

Estimated 1975 conditions differ from these 1960 patterns of procurement and distribution. Hog production declines approaching 20 percent may be anticipated in both Eastern and Western Ohio (Table 10). Both regions may be obliged to import hogs to meet slaughter requirements. Western Ohio packers may find optimum procurement sources in Indiana and Illinois while Eastern packers may find Illinois the only favorable procurement source. Western Ohio may become a major exporter, supplying pork to Eastern Ohio among several optimum markets. The position of Western Ohio packers as suppliers of

[22]These insights were obtained from survey data in a related study. They emphasize the significance of slaughter activity in other species to hog slaughter location. U.S. Department of Agriculture data indicate that in 1960 12.5 percent of the plants in Ohio slaughtered only hogs, while 34.4 percent slaughtered hogs in combination with other species.

pork may be quite competitive relative to other Corn Belt regions, but may anticipate increased competitive pressure from Southern areas such as Virginia, Kentucky and Tennessee. Pork exports will reflect this pressure and will show increased emphasis by Ohio packers on Eastern and Northeastern markets.

APPENDIX A

Appendix Table 1 — Retail Price of Beef and Pork, Per Capita Pork & Beef Consumption and Per Capita Disposable Income, United States, 1950-1960

Year	Per Capita Consumption[1] Pork	Per Capita Consumption[1] Beef	Retail Pork Price[2]	Retail Beef Price[2]	Per Capita Disposable Income
	(lbs.)	(lbs.)	(cts)	(cts)	(dollars)
1950	69.2	63.4	55.1	69.3	1369
1951	71.9	56.1	59.2	81.8	1473
1952	72.4	62.2	57.5	76.5	1520
1953	63.5	77.6	63.5	60.5	1582
1954	60.0	80.1	64.8	58.5	1582
1955	66.8	82.0	54.8	58.9	1660
1956	67.3	85.4	52.1	57.8	1742
1957	61.1	84.6	60.2	63.5	1804
1958	60.2	80.5	64.8	75.1	1826
1959	67.6	81.4	57.1	76.8	1905
1960	65.3	85.2	56.6	74.2	1969

[1]Carcass-equivalent weight

[2]Average price of retail cuts per pound, exclusive of certain minor products.

Source. Breimyer, H. F., "Demand and Prices for Meat," Economic Research Service, United States Department of Agriculture Technical Bulletin Number 1253 December, 1961, pages 47 and 52

Appendix Table 2 — Percent of United States Commercial Hog Slaughter Plus Farm Hog Slaughter, 29 Regions, United States, 1947-1961

Region	1947	1948	1949	1950	1951	1952	1953
1	1.50	1.29	1.23	1.18	1.12	1.16	1.19
2	1.85	1.96	1.95	1.87	1.85	1.87	2.02
3	1.32	1.01	1.33	1.50	1.65	1.83	1.81
4	1.34	1.47	1.31	1.25	1.26	1.31	1.38
5	3 86	3.72	3.56	3.57	3.39	3.61	3.59
6	1.55	1.64	1.61	1.77	1.79	1.84	1.99
7	.41	.46	.39	.38	.39	.39	.38
8	5.08	4.88	4.44	4.38	4.45	4.68	4.88
9	.75	.63	.60	63	.59	.72	.81
10-11	4.81	5.01	4.65	4.95	4.87	4.97	5.07
12	2.29	2.64	2.35	2.31	2.36	2.49	2.48
13	4.62	4.56	4 90	4.70	4.50	4.32	4.92
14	3.20	3.55	3.49	3.80	3.81	3.88	3.84
15	2.35	2.33	2.10	1.87	1.70	1.75	1.79
16	11.67	11.79	12.08	11.75	11.84	12.12	12.06
17a	13.79	13.12	14.74	15.22	15.23	15.17	15.96
17b	10.54	10.64	10.46	10.35	10.49	10.05	9.67
17c	5.15	5.49	4.84	4.96	5.43	5.16	4.99
18	1.56	1.43	1.31	1.19	1.11	1.08	1.04
19	3.48	3.79	3.67	3.30	3.33	3.57	3.57
20	8.74	8.05	8.71	8.76	8.38	7.52	7.01
21	4.19	4.53	3.91	3 95	4.11	4.13	3.58
22	.53	.58	.60	.58	.59	.60	.59
23	1.04	.88	1.01	1.04	1.04	.99	.92
24	.19	.24	27	29	.27	.28	.24
25	1.45	1.43	1.48	1.52	1.48	1.48	1.32
26	.32	.32	.39	.36	.35	.34	.35
27	2.42	2.53	2.62	2.58	2.69	2.69	2 53
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Appendix Table 2 (Continued)

Region	1954	1955	1956	1957	1959	1958	1960	1961
1	1.23	1.19	1.13	1.02	.92	.66	.75	.74
2	1.96	1.99	1.99	2.16	2.01	1.89	1.94	2.12
3	1.86	1.94	2.07	1.89	1.82	1.47	1.59	1.48
4	1.30	1.27	1.30	1.33	1.22	1.02	1.01	.96
5	3.60	3.25	3.22	3.18	3.48	3.26	3.17	3.44
6	2.01	2.09	2.24	2.38	2.39	2.44	2.62	2.61
7	.37	.34	.33	.31	.29	.29	.30	.27
8	4.65	4.35	4.58	4.72	4.58	4.41	4.82	4.71
9	.76	.69	.72	.76	.74	.71	.70	.68
10-11	5.20	5.21	5.32	5.36	5.15	4.82	5.19	4.72
12	2.03	2.07	2.02	1.95	2.02	1.78	1.88	1.90
13	4.61	4.82	4.94	5.47	5.75	5.90	6.27	6.12
14	3.68	3.89	4.00	4.40	4.47	4.66	5.10	5.09
15	1.63	1.62	1.65	1.81	1.84	2.03	2.08	2.06
16	12.25	12.05	11.53	11.29	11.53	11.49	11.31	11.41
17a	16.47	16.17	15.85	15.81	16.82	18.27	18.12	18.13
17b	9.69	8.86	9.00	8.89	8.14	7.58	6.75	6.76
17c	5.00	5.06	5.17	4.96	4.82	5.19	5.01	5.07
18	.92	.88	.88	.89	.86	.80	.82	.83
19	3.71	3.57	3.33	3.18	3.26	3.31	3.05	3.30
20	7.59	8.75	8.46	8.94	8.72	9.34	8.87	9.14
21	3.60	3.75	3.87	3.59	3.49	3.41	3.17	3.13
22	.60	.57	.70	.57	.61	.63	.62	.60
23	.88	.86	.85	.81	.73	.67	.80	.72
24	.24	.26	.30	.31	.32	.32	.31	.30
25	1.24	1.43	1.45	1.39	1.36	1.47	1.45	1.41
26	.34	.34	.35	.42	.42	.39	.37	.35
27	2.58	2.73	2.75	2.41	2.21	2.09	1.95	1.95
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: "Commercial Livestock Slaughter," Crop Reporting Board, U.S. Department of Agriculture, SB 231, July 1958; Livestock Slaughter 1960, MtAn 1-2-1 (61), Crop Reporting Board, USDA, April 1961; Livestock Slaughter 1961, MtAn 1-2-1 (62), Crop Reporting Board, USDA, April 1962; "Meat Animals: Farm Production, Disposition and Income," Revised Estimates, SB 113, July 1952; SB 184, June 1956; MtAn 1-1, April 1962, Crop Reporting Board, USDA.

Appendix Table 3 — Percent of United States Hog Marketings Plus Farm Slaughter, 29 Regions, United States, 1947-1961

Region	1947	1948	1949	1950	1951	1952	1953
1	0.32	0.33	0.33	0.28	0.27	0.29	0.33
2	0.45	0.41	0.43	0.31	0.29	0.33	0.34
3	0.19	0.20	0.18	0.17	0.18	0.21	0.21
4	0.41	0.43	0.44	0.40	0.41	0.41	0.52
5	1.13	1.18	1.14	1.01	1.04	1.08	1.20
6	1.08	1.21	1.15	1.14	1.13	1.12	1.18
7	0.37	0.41	0.38	0.34	0.31	0.27	0.28
8	4.46	4.64	4.24	4.27	4.14	4.46	4.68
9	0.59	0.64	0.56	0.50	0.54	0.65	0.64
10-11	5.63	5.74	5.58	5.38	5.22	5.08	5.20
12	1.48	1.34	1.46	1.46	1.48	1.51	1.15
13	7.71	8.06	8.01	8.44	7.99	8.10	8.61
14	3.65	4.08	4.06	3.98	3.75	3.61	3.14
15	2.57	2.53	2.44	2.48	2.36	2.37	2.31
16	10.66	10.15	10.63	10.78	10.54	10.86	11.06
17a	21.39	20.64	21.56	22.33	22.96	22.79	24.21
17b	11.02	11.28	10.94	11.35	11.23	11.62	12.23
17c	6.64	6.71	6.81	7.18	7.38	6.39	6.47
18	2.22	2.25	2.13	2.02	1.70	1.50	1.29
19	4.32	3.80	4.09	3.41	3.50	3.95	3.63
20	7.16	6.89	6.75	6.60	7.39	7.41	6.42
21	3.60	3.90	3.52	3.39	3.56	3.33	2.31
22	0.80	0.81	0.86	0.66	0.67	0.74	0.55
23	0.45	0.53	0.52	0.51	0.49	0.45	0.31
24	0.14	0.16	0.15	0.14	0.12	0.13	0.11
25	0.63	0.64	0.65	0.53	0.45	0.52	0.49
26	0.17	0.22	0.19	0.15	0.15	0.14	0.11
27	0.76	0.82	0.80	0.79	0.75	0.68	0.69
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Appendix Table 3 (Continued)

Region	1954	1955	1956	1957	1958	1959	1960	1961
1	0.29	0.28	0.29	0.29	0.27	0.24	0.28	0.23
2	0.31	0.27	0.28	0.27	0.24	0.21	0.24	0.20
3	0.18	0.26	0.31	0.25	0.21	0.16	0.16	0.13
4	0.43	0.39	0.41	0.39	0.36	0.31	0.32	0.29
5	1.01	0.95	0.99	0.97	0.81	0.73	0.85	0.81
6	1.00	0.95	0.94	1.07	1.03	0.89	0.98	0.97
7	0.24	0.23	0.26	0.21	0.16	0.16	0.17	0.15
8	4.77	4.30	4.68	5.08	5.10	5.08	5.21	4.69
9	0.55	0.54	0.53	0.58	0.49	0.54	0.49	0.48
10-11	5.22	4.99	5.10	5.23	4.67	4.40	4.59	4.61
12	1.38	1.38	1.40	1.32	1.29	1.28	1.34	1.28
13	8.56	8.28	8.57	8.74	8.35	8.59	8.85	9.15
14	3.25	3.21	3.80	4.18	3.91	3.82	4.24	4.15
15	2.13	2.06	2.30	2.44	2.33	2.13	2.37	2.19
16	11.61	11.90	10.77	10.99	11.65	11.49	10.73	10.78
17a	24.36	24.35	23.04	22.16	22.70	22.63	22.74	22.50
17b	12.32	12.56	13.11	13.76	14.17	13.71	13.79	14.02
17c	6.70	6.35	7.15	7.23	6.89	6.66	6.88	7.10
18	1.05	1.07	1.34	1.38	1.01	0.93	1.08	0.97
19	3.85	4.28	3.83	3.69	4.17	4.73	3.66	4.06
20	6.60	6.98	6.37	5.67	6.25	6.91	6.66	6.97
21	2.20	2.40	2.53	2.12	1.89	2.33	2.27	2.17
22	0.46	0.45	0.52	0.49	0.53	0.56	0.54	0.59
23	0.28	0.27	0.29	0.28	0.26	0.31	0.32	0.30
24	0.11	0.11	0.12	0.13	0.12	0.11	0.13	0.12
25	0.45	0.51	0.50	0.48	0.48	0.55	0.52	0.53
26	0.10	0.09	0.10	0.12	0.12	0.10	0.11	0.10
27	0.59	0.59	0.47	0.49	0.54	0.44	0.48	0.46
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: "Meat Animals: Farm Production, Disposition and Income," Revised Estimates Statistical Reporting Service, U.S. Department of Agriculture, SB 113, June 1956; SB 184, June 1956; SB 284, May 1961; MtAn 1-1, April 1961, MtAn 1-1, April 1962.

Appendix Table 4 — Time Series Data for Estimating Percentage Change in Transportation Rates for 1975

Year	Index of Rail Freight Rates 1947-49 = 100		Wholesale Price Index	Deflated Rail Freight Rates			
				1947-49 = 100		1960 = 100	
	Livestock	Meat		Livestock	Meat	Livestock[1]	Meat[2]
1948	103	103	104.4	98.7	98.7	77.2	96.8
1949	111	112	99.2	111.9	112.9	87.5	110.7
1950	114	115	103.1	110.6	111.5	86.5	109.3
1951	117	119	114.8	101.9	103.7	79.7	101.7
1952	127	127	111.6	113.8	113.8	89.0	111.6
1953	130	130	110.1	118.1	118.1	92.3	115.8
1954	130	130	110.3	117.9	117.9	92.2	115.6
1955	130	130	110.7	117.4	117.4	91.8	115.1
1956	136	136	114.3	119.0	119.0	93.0	116.7
1957	146	144	117.6	124.1	122.4	97.0	120.0
1958	154	136	119.2	129.2	114.1	101.0	111.9
1959	153	123	119.5	128.0	102.9	100.1	100.9
1960	153	122	119.6	127.9	102.0	100.0	100.0

[1]The estimating equation fit by least-squares for live animal rates is:

$$Y_h = 91.33 + 1.23846X$$

where Y_h is the transportation rate for hogs in time X as a percent of the 1960 rate, and X is time measured in years with 1954 being the origin (X = 0 for 1954). Thus, for 1975, X = 21 and $Y_h 1975 = 91.33 + 1.23846\ (21) = 117.34$

[2]The estimating equation fit by least-squares for meat rates is·

$$Y_m = 109.70 + .24725\ X$$

where Y_m is the transportation rate for meat in time X as a percent of the 1960 rate, and X is time measured in years with 1954 being the origin (X = 0 for 1954). Thus, for 1975, X = 21 and $Y_m 1975 = 109.70 + .24725\ (21) = 114.89$

Source: Index of transportation rates: *Marketing and Transportation Situation.* ERS USDA, Ocober 1961. Also Wholesale Price Index: *Economic Report of the President,* Table 40B, p. 254, January 1962.

APPENDIX B

METHODOLOGY

The construction and completion of transportation models can be structured into several phases:

1. Collection of essential data.
2. Determination of regional boundaries in the market area.
3. Determination of surplus - and deficit-producing regions.
4. Arriving at a first approximation of product flows.
5. Iteration of product flows to derive an optimum shipment pattern.

Spatial equilibrium models use the transportation model as an integral step, but regard consumption as a function of price rather than fixed. The completion of these models follows the same procedure but incorporates the additional steps:

2 (a) Determination of regional demand functions.
2 (b) Determination of a set of product price differentials between regions.
2 (c) Determination of an equilibrium set of regional prices.
6. Iteration through steps 2 (b) to 5 to determine an optimum shipment pattern and the associated set of regional equilibrium prices and quantities.

Data Requirements—

Data inputs necessary for transportation model analysis include estimates of (1) regional production, (2) regional consumption and (3) transportation costs. Spatial equilibrium analysis requires in addition (4) functional estimates of regional demand relationships.

The collection of data usually involves a survey of published series and research literature accompanied by estimates derived from original data. Production and consumption data frequently are given. Transportation cost functions and price-consumption relationships are usually estimated. Data which will provide functional estimates by regions probably will not be available or may be prohibitively cumbersome. Functions representative of the total market area probably will have to be modified to represent each region.

Determination of Regional Boundaries—

The primary objective of regional demarcation is to divide the market area into meaningful and homogeneous production and/or consumption areas. To be meaningful there must be enough regions so that solutions are not overgeneralized. In general, the more complicated procedure of the spatial equilibrium model in relation to the transportation model restricts the number of regions which may be conveniently handled.

Determination of Surplus-and Deficit-Producing Regions—

Both transportation and spatial equilibrium models are concerned with the allocation of commodity shipments between each possible pair of regions at the lowest total transportation cost. Since production and consumption occur simultaneously in all regions the only commodity considered for shipment into or out of the region is the net difference between the amount produced and the amount consumed. If any processing occurs between production and consumption it is necessary to make appropriate adjustments to production-equivalent or consumption-equivalent weights so that amounts produced and consumed in the total market area remain equal.

Commodity price level is not a consideration in using transportation models. Therefore, regional production and consumption, not being affected by price, are fixed, and determination of surplus and deficit regions is a simple procedure. When the spatial equilibrium approach is employed, the identification of surplus- and deficit-producing regions and determination of the related regional prices is an integral part of the procedure, and surplus-and deficit-producing regions may vary with successive iterations. For either model, iterative steps begin with an initial approximation of product flows.

The First Approximation of Optimum Product Flows—

When three or more regions are involved the optimum pattern of shipment between possible pairs of regions is not straightforward. If the investigator has no a priori basis for predicting what the optimum pattern should be, the "Vogel Approximation"[23] is a method of estab-

[23]This approximating technique was first presented at the Industrial Engineering Quality Control Conference at Milwaukee, Wisconsin, in 1954, and was reported in research by G. G. Judge. The methods and examples used here parallel those of Judge, G. G. and Wallace, T. D., as found in "Spatial Price Equilibrium Analysis of the Livestock Economy," Oklahoma Agricultural Experiment Station Technical Bulletin TB-78, Stillwater, June, 1959.

lishing a first feasible basis for solving the transportation problem. For example, suppose there are eight regions arranged as surplus- and deficit-producing (exporting and importing) as in Appendix Table 5 (generalization to any number of regions is apparent.)

Appendix Table 5 — Commodity Surplus and Deficit, by Regions, and, Transportation Cost Between Regions, Hypothetical Circumstance.

Exporting Regions (i)	Importing Regions (j)					Total Exports (Surplus) (a_i)
	4	5	6	7	8	
		(Transportation Costs)				(Tons)
1	1	3	4	6	3	50
2	0	5	6	9	2	80
3	8	5	3	2	9	120
Total Imports (Deficit) (b_j)	90	25	35	40	60	250

Total exports and imports necessarily are of equal tonnage. Transportation costs are derived from estimating equations for shipments between each possible pair of regions and entered in the table. Distance between regions is usually obtained by consulting maps for feasible commercial routes. The unit cost of shipment from Region 3 to Region 7, for example, is 2.

Each exporting region can ship to any importing region. The problem is one of allocating the surplus in a way that satisfies all deficit region requirements at a minimum total transportation cost (sum of the products of unit cost of shipment times volume for each corresponding shipment.) There are fifteen cells in the table representing the only possible interregional shipments. At most seven of these 15 possible shipments need to occur. In general this method assures that, if a minimum cost shipment pattern exists, there will be at most m + n - 1 shipments, where m is the number of exporting regions and n is the number of importing regions.[24]

[24]The fifteen possible shipments (x_{ij}) represented by cells in Appendix Table 5 are related to each other, to each region's requirements (a_i and b_j) and to the transportation costs (c_{ij}) by a cost equation and a system of 8 equations in the 15 unknown shipments (x_{ij}). x_{ij} represents the shipment of product from region i to region j and the value of x_{ij} represents the level of the shipment. In equation form the transportation model is:

Minimize C, where

$$(0)\quad C = c_{14}x_{14} + c_{15}x_{15} + c_{16}x_{16} + c_{17}x_{17} + c_{18}x_{18} + c_{24}x_{24} + c_{25}x_{25} + c_{26}x_{26} + c_{27}x_{27} + c_{28}x_{28} + c_{34}x_{34} + c_{35}x_{35} + c_{36}x_{36} + c_{37}x_{37} + c_{38}x_{38}$$

subject to

$$(1)\quad x_{14} + x_{15} + x_{16} + x_{17} + x_{18} = a_1 = 50$$
$$(2)\quad x_{24} + x_{25} + x_{26} + x_{27} + x_{28} = a_2 = 80$$
$$(3)\quad x_{34} + x_{35} + x_{36} + x_{37} + x_{38} = a_3 = 120$$
$$(4)\quad x_{14} + x_{24} + x_{34} = b_1 = 90$$
$$(5)\quad x_{15} + x_{25} + x_{35} = b_5 = 25$$
$$(6)\quad x_{16} + x_{26} + x_{36} = b_6 = 35$$
$$(7)\quad x_{17} + x_{27} + x_{37} = b_7 = 40$$
$$(8)\quad x_{18} + x_{28} + x_{38} = b_8 = 60$$

Working with the data provided in Appendix Table 5, the "Vogel Approximation" method selects a set of shipments under a system of priorities which attempt to reach the optimum solution without further iteration.

The "Vogel Approximation" is a systematic method of obtaining a first feasible solution to equations (1) - (8). Actually, the equations never need to be specifically stated. The nature of this equation system insures that only n+m−1 (in this case, 7) shipments can be determined since there are only n+m−1 independent equations among the n + m equations in the system. Moreover, the fundamental theorem of linear programming (of which transportation models are a special case) states that the number of non-zero x_{ij}'s (shipments) occurring in the solution will be no greater than n+m−1.

If the number of positive shipments is less than n+m-1, the solution is said to be "degenerate." In such cases it will be necessary to treat one or more zero level shipments as positive shipments in order to have n+m−1 "shipments" being made. The necessity and procedure for this will be discussed. Generally, the wider the choice of cost alternatives available to each region, the lower will be its priority in receiving or distributing the necessary quantity of the commodity. As more of the alternatives available to each region disappear, the higher its priority rises until it becomes imperative that its "problems" be resolved. The general procedure for estimating an optimum under this system is presented in Appendix Table 6.

(1) Construct the upper left part of Appendix Table 6, entering the computed unit transportation cost in the upper righthand corner of each cell, leaving room for additional entries in the cell.

Appendix Table 6 — Format, Vogel Approximation of Optimum Shipment Pattern, Hypothetical Circumstance.

Exporting Regions (i)	Importing Regions (j) 4	5	6	7	8	Total Exports (a_i)	Row Cost Differences						
1	10^{1}	^{3}	^{4}	^{6}	40^{3}	50	2	2	2	0	X_4		
2	80^{0}	^{5}	^{6}	^{9}	^{2}	80	2	2	X_2				
3	^{8}	25^{5}	35^{3}	40^{2}	20^{9}	120	1	2	2	2	2	2	2
Total Imports (b_j)	90	25	35	40	60	250							

Column Cost Differences

1	2	1	4	1
1	2	1	X_1	1
7	2	1		6
X_8	2	1		6
	5	3		9
	5	3		X_5
	X_6	3		
		X_7		

(2) Observe Row 1 (all possible export opportunities for Region 1). Select the two lowest transportation costs in the row (1 and 3) and enter the positive difference between these two costs (2) at the right of the table under the heading "Row Cost Differences," Do the same for each row and column, entering the column cost differences beneath the table.

(3) Select the largest value that has been attained from this initial determination of row and column cost differences. It does not matter whether the value represents a row or a column cost difference. (In this case, the value is 4.)

(4) Examine the row or column in the table from which this cost difference was drawn, and select the cell with the smallest transportation cost. (In this case, the cell representing shipments from Region 3 to Region 7 displays the lowest transportation cost: 2.) Assign to this cell the maximum shipment that it can attain. The maximum will be either the total needs of the importing region or the total available from the exporting region. Mark out the row or column that has been satisfied, eliminating it from further consideration and enter some symbol of termination after the appropriate row cost difference or below the column cost difference. (In this case, the maximum the cell could receive was the total quantity needed by Region 7. Column 7 is therefore marked out, and X_1 is entered below the column cost difference.) Also, subtract from the total exports or total imports the amount that has been shipped or received. (In this case, the export capacity of Region 3 has been reduced from 120 to 80 units remaining available for shipment.)

(5) Re-determine the row and column cost differences not considering marked out rows and columns. If a column has just been removed from consideration, then all row cost differences are subject to re-examination. Column cost differences remain unchanged. If a row has been removed from consideration, then remaining row cost differences remain unchanged, but column cost differences must be examined for probable changes.

(6) After all row and column cost differences have been re-established, the procedure from (2) through (5) is repeated until all shipments have been made.

Preparation for Reiteration

In small models the Vogel Approximation often will provide an optimum solution without further iterations. The determination of whether or not a solution (the Vogel Approximation or any other) provides an optimum requires an additional step which also serves as a basis for introducing a new shipment in the second iteration.[25]

The shipment pattern derived from the Vogel Approximation (or from any method of finding a solution) is reconstructed in tabular form, putting the unit cost of transportation for each of the assumed shipments in the upper right hand corner of the corresponding cell.

[25]For a more detailed discussion of the method for finding the optimum solution to a transportation model see Dorfman, Robert, Paul A. Samuelson, and Robert Solow; "Linear Programming and Economic Analysis." New York: McGraw-Hill Book Co., Inc., 1958, Chapter 5.

Appendix Table 7 — Reconstruction of Vogel Approximation Shipment Pattern, Check for Optimum and Price Differentials, Hypothetical Circumstance.

Exporting Regions (i)	Importing Regions (j) 4	5	6	7	8	Total Exports (a_i)	Price Differentials (U_i)
1	$10^{\underline{1}}$	-4^{-1}	-7^{-3}	-10^{-4}	$40^{\underline{3}}$	50	6
2	$80^{\underline{0}}$	-7^{-2}	-10^{-4}	-14^{-5}	0^{2}	80	7
3	-1^{7}	$25^{\underline{5}}$	$35^{\underline{3}}$	$40^{\underline{2}}$	$20^{\underline{9}}$	120	0
Total Imports (b_j)	90	25	35	40	60	250	—
Price Differentials (V_j)	7	5	3	2	9	—	—

For example, consulting the initial shipment pattern in Appendix Table 7, Region 1 ships to Regions 4 and 8 and the unit transportation costs are 1 and 3, respectively.

The entire set of shipments are those from region 1 to regions 4 and 8, from Region 2 to Region 4, and from Region 3 to Regions 5, 6, 7, and 8.

On the basis of this initial shipment pattern and the corresponding unit costs of transportation, it is possible to estimate the added costs or savings which could be attained if some other shipment were to take place. The numbers in the cells of Table 7 for which shipments do not occur give us the information on the added costs or savings of making each of these shipments. The number in the upper right hand corner of each cell for which the initial assumed shipment is zero represents the *indirect* cost (indicated by a negative value) or savings (positive value) which would be realized if this shipment occurs. The nature of these indirect costs is such that the differences in indirect costs between any corresponding elements of a pair of rows or a pair of columns is equal to the difference between unit transportation costs of the *assumed* shipments involving corresponding elements of the pair of rows or pair of columns. Consider rows (regions) 1 and 3. Both regions ship to Region (column) 8. Then the difference in unit transportation cost between row 3 and 1 is 9 minus 3, or 6, and the indirect costs for row 1 are 6 less than each transportation cost (for assumed shipments) or indirect cost in row 3. The indirect costs for Region 1 shipping to Regions 5, 6, and 7 are 5-6 = -1, 3-6 = -3, and 2-6 = -4, respectively. The indirect costs for Region 3 shipping to Region 4 is found by adding the row 3 and row 1 difference to the transportation cost of shipping from 1 to 4, ie. 1+6 = 7. By working with pairs of columns, the indirect costs for row 2 can be found. For example since the indirect cost from Region 3 to Region 4 is 7 and the transportation cost from Region 3 to Region 5 (one of the assumed shipments) is 5, the difference between the indirect cost of column 1 and 2 is equal to 2. Thus the indirect cost from Region 2 to Region 5 is 0-2= -2. By this process the indirect cost can be found for each cell.[26]

When the upper right hand corner of each cell is filled, either with the actual transportation cost or with the computed indirect cost, determination of whether or not the assumed shipment pattern represents an optimum requires one more step. The indirect costs of the cells for which no shipment is assumed must be compared with the direct costs (unit transportation cost) of making that shipment. For each cell find the difference, indirect costs minus unit transportation costs (Appendix Table 6). For example, this difference for Region 3 to Region 4 is 7-8= -1. These differences are entered in the cells of Appendix Table 7 for those shipments which do not occur. If all of these differences are *negative or zero,* the assumed shipments represent an optimum and further iterations are unnecessary. If some differences of indirect and direct costs are zero for non-occurring shipments (e.g. row 2, column 8 of Appendix Table 7), they are interpreted to mean that an alternate optimum (equal minimum cost) solution exists and that the shipments involving these "zero difference" cells could occur without increasing the total transportation cost. If any one of the cost differences is positive, the indirect cost, i.e. saving, of that shipment is greater than the direct cost of making that shipment. This indicates that an optimum has not been reached and that further iterations are needed to find the optimum shipment pattern. The appearance of positive cost differences in first iteration should be expected, with the number of iterations necessary to find the optimum varying directly with the number of regions in the model.

Subsequent Iterations

The iteration process is simple. The objective of the process is to introduce new shipments, one at a time, *eliminating a shipment of the previous solution for each new shipment,* so that each of the differences between indirect costs and transport costs becomes less than or equal to zero.

The Addition of a Single Shipment

The new shipment to be introduced is the one which has the *largest positive* cost difference. If the largest positive cost difference is found in two or more cells, select that cell for which the largest shipment can be made. The process of introducing a new shipment and altering existing shipments must be done in a way that does not violate the rim requirements, i.e. the total amount that is to be shipped out of or into each of the regions. In order to retain the condition that there is no more than n+m—1 shipments, for every shipment added another shipment must be omitted.

[26]In the case of degenerate solutions mentioned previously, it may be impossible to complete the calculation of indirect costs on the basis of known transportation charges for existing shipments. In this event, additional shipments of zero value, accompanied by corresponding transportation charges, must be assigned to strategic cells. These cells are those which will enable us to compute all indirect costs by the procedure outlined. Enough zero value shipments must be assigned to bring the total number of shipments up to n+m-1. It will then be possible to determine all the indirect costs in the table.

Appendix Table 8 — Non-Optimal Shipment Pattern and Associated Cost Differences for Hypothetical Case.

Export Region	Import Region 4	5	6	7	8	Total (tons) Exports (a_i)
1	$10^{\underline{1}}$	-4^{-1}	$35^{\underline{4}}$	-10^{-4}	$5^{\underline{3}}$	50
2	$80^{\underline{0}}$	-7^{-2}	-3^{3}	-14^{-5}	0^{2}	80
3	-1^{7}	$25^{\underline{5}}$	$+7^{10}$	$40^{\underline{2}}$	$55^{\underline{6}}$	120
Total Imports (b_j) (tons)	90	25	35	40	60	250

An example will be used to indicate the method of changing shipment patterns. In the hypothetical problem assume that the Vogel approximation had given the solution indicated by Appendix Table 8.

Assume that the Vogel approximation led to a solution which was not the optimal one. Let the numbers in the cells for which the number in the upper-right corner is underlined represent amounts shipped. As before, the numbers in the upper-right of each cell are indirect costs of making that shipment and the numbers in the non-shipment cells (the upper right corner number is not underlined for non-shipment cells) represent the cost differences. These shipments satisfy the rim requirements. but the cost differences for each cell is not zero or negative. The cell for Region 3 and 6 has a cost difference of 10-3 = 7. Since this is the only cell with a positive cost difference, a new shipment pattern including shipment from Region 3 to 6 should be determined. To retain 7 shipments one of the shipments in the present pattern must be eliminated. To determine the new pattern of shipments consider what would be the effect on existing shipments if 1 unit of product were shipped from Region 3 to Region 6. Starting in cell 3-6 (the cell at the intersection of the Region 3 row and Region 6 column) draw a path composed of vertical or horizontal straight line segments such that all changes in direction of the path are right angles and these "corners" occur only in cells where shipments are positive. *This "path" must begin and end in cell* 3-6. It may, but need not, cross over itself. Thus, we start in 3-6 and proceed "north" to cell 1-6 (we cannot turn at cell 2-6). Here we turn a right angle and proceed "east" to cell 1-8, where we turn "south" to 3-8, where we turn "west" to 3-6 and complete the loop. The shipments at the corners of this path are the only ones which will be affected by making shipment 3-6 positive. The effect on each shipment is determined in the following way. After leaving the origin (cell 3-6), the odd numbered turns (first, third, fifth, etc.) in the path will have decreases in shipments while the even numbered (second, fourth, sixth, etc.) turns will have an increase in shipments. Thus if the shipment in cell 3-6 is increased to 1 unit, the shipments in cell 1-6 and cell 3-8 will be *reduced* by 1 unit and the shipment at the second corner (cell 1-8) will *increase* by one unit in order to satisfy the rim requirements. If we continue to increase the amount of the shipment in cell 3-6, we see that when this new shipment becomes 35 units, the shipment in cell 1-6 becomes zero. Thirty-six units could not be shipped from Region 3 to 6 because this would require a negative shipment in cell 1-6. *This is not permissible.* Four shipments are changed in this iteration. Cell 3-6 goes from 0 to 35 units, cell 1-6 goes from 35 to 0 units, cell 1-8 goes from 5 to 40 units, and cell 3-8 goes from 55 to 20 units. This new pattern of shipments can be recognized as the previously determined optimum one, a fact which can be verified by computing the cost differences for each cell and noting that all are non-positive.

In regard to this process of determining the new shipment pattern it is important to recognize three points: (1) A complete path (loop) as described can always be found which begins and ends in a cell where a new shipment is to be made. Only *one* path will exist for each non-shipment cell and this path may, but need not, cross-over itself. The path may be traversed in either direction. In the example, if we had turned "west" at cell 1-6, we would have been unable to find a path back to cell 6-3 unless we had retraced some of our steps. (2) The path begins at the cell representing the new shipment and continues alternately subtracting and adding the shipment quantity at the successive corners. (3) The amount of the new shipment is equal to the amount of the smallest of the shipments at the "subtraction corners." The shipment at the "smallest subtraction corner" will not be in the new shipment pattern.

Commodity Price Differentials

The optimum shipment pattern that evolves in the final iteration will yield a set of value (or price) differentials (U_i and V_j, Appendix Table 7) representing the difference in value of the commodity among regions relative to a region selected as the base region. These price differentials are among the necessary inputs to estimation of regional consumption in spatial equilibrium analysis. In Appendix Table 7, Region 3 was used as the base region.

When a surplus region is chosen as a base region the value differential of each deficit region relative to the base region is equal to indirect cost (number in upper-right corner of each cell) of the shipment from the base region to the deficit. For shipments which actually occur, indirect costs equal per unit transport costs. Thus in Appendix Table 7, the product is worth 7, 5, 3, 2, and 9 units more in Regions 4, 5, 6, 7 and 8, respectively, than in Region 3. Value differentials between the base surplus region and other surplus regions are determined by subtracting the indirect cost for the surplus region to any deficit region from the indirect cost for the base region to the *same* deficit region. In Appendix Table 7, the indirect costs from Regions 1, 2, and 3 (base) to Region 8 are 3, 2, and 9, respectively. The value differential for surplus Region 1 is 9-3 =6, and for Region 2 is 9-2=7. The U_i's and V_j's are these value differentials. Value differentials may be positive, negative or zero relative to the base region. For our example, all differentials are positive indicating that product value is greater in all other regions than Region 3, the base region.

The value differentials and indirect costs can be determined by solving a set of m+n—1 linear equations. These equations are based on the observation that value differences between regions can be no greater than transport costs, but must be this large. Thus for each shipment which occurs we have:

$$V_j - U_i = C_{ij}$$

where V_j and U_i are price differentials and C_{ij} is the per unit transport costs from region i to region j. In our hypothetical example, there are m+n—1 = 7 of these equations.

$$V_4 - U_1 = 1 = C_{14}$$
$$V_4 - U_2 = 0 = C_{24}$$
$$V_5 - U_3 = 5 = C_{35}$$
$$V_6 - U_3 = 3 = C_{36}$$
$$V_7 - U_3 = 2 = C_{37}$$
$$V_8 - U_3 = 9 = C_{38}$$
$$V_8 - U_1 = 3 = C_{18}$$

Setting the value (U_3) for the base region equal to zero, we get the set of value differentials recorded in Appendix Table 7.

The indirect costs (C_{ij}) for non-shipment cells can be determined from

$$V_j - U_i = C'_{ij}$$

where the value differentials determined above are used. For example, the indirect cost from Region 1 to Region 6 is $V_6 - U_1 = 3\text{-}6 = \text{-}3 = C'_{16}$. Note that C'_{ij} will always be less than or equal to C_{ij}, the transport costs, in the optimal solution.

Iterative Procedures in Spatial Equilibrium Analysis

The commodity price differentials that are derived as described are necessary in estimating regional consumption as set forth in the equations in footnote 9 in the text. The spatial equilibrium model is therefore initiated through the following sequence: (1) An optimum shipment pattern is derived with a transportation model. (2) The optimum solution yields a set of commodity price differentials related to a base region (though a base region *price* is not yet determined). (3) The price differentials are employed in equation 7 (footnote 9) to derive a base region price. (4) The base region price and differentials are employed in equation 6 (footnote 9) to determine per capita consumption in each region. (5) Per capita consumption is multiplied by population in each region. (6) Surplus and deficit regions are determined. (7) A Vogel Approximation is made. (8) Price differentials are obtained from the tableau. (9) Steps (3) through (8) are repeated through successive iterations *until the last two iterations yield identical sets of price differentials indicating that an optimum solution has been reached.*